PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXXIV.

SESSION 1919-1920.

LIVERPOOL:
C. Tinling & Co., Ltd., Printers, 53, Victoria Street.

1920.

CONTENTS.

I.—Proceedings.

II.—Transactions.

PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

OFFICE-BEARERS AND COUNCIL

Ex-Presidents:

1886—1887 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—1888 J. J. DRYSDALE, M.D.
1888—1889 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—1890 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—1891 T. J. MOORE, C.M.Z.S.
1891—1892 T. J. MOORE, C.M.Z.S.
1892—1893 ALFRED O. WALKER, J.P., F.L.S.
1893—1894 JOHN NEWTON, M.R.C.S.
1894—1895 Prof. F. GOTCH, M.A., F.R.S.
1895—1896 Prof. R. J. HARVEY GIBSON, M.A.
1896—1897 HENRY O. FORBES, LL.D., F.Z.S.
1897—1898 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—1899 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E.S.
1910—1911 Prof. R. NEWSTEAD, M.Sc., F.R.S.
1911—1912 J. H. O'CONNELL, L.R.C.P.
1912—1913 JAMES JOHNSTONE, D.Sc.
1913—1914 C. J. MACALISTER, M.D., F.R.C.P.
1914—1915 Prof. J. W. W. STEPHENS, M.D., D.P.H.
1915—1916 Prof. ERNEST GLYNN, M.A., M.D.
1916—1917 Prof. J. S. MACDONALD, L.R.C.P., F.R.S.
1917—1918 JOSEPH A. CLUBB, D.Sc.
1918—1919 Prof. W. RAMSDEN, M.A., D.M.

SESSION XXXIV, 1919-1920.

President:

HUGH R. RATHBONE, M.A., J.P.

Vice-Presidents:

Prof. W. RAMSDEN, M.A., D.M.
Prof. W. A. HERDMAN, C.B.E., D.Sc., F.R.S.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

MAY ALLEN, B.A.

Hon. Secretary:

W. RIMMER TEARE, A.C.P.

Council:

R. C. BISBEE, M.Sc. (Mrs.)
S. T. BURFIELD, B.A.,
R. CATON, M.D., F.R.C.P.
J. A. CLUBB, D.Sc.
J. W. CUTMORE.
G. ELLISON.
E. L. GLEAVE, M.Sc. (Miss)
W. S. LAVEROCK, M.A., B.Sc.
Prof. J. JOHNSTONE, D.Sc.
Prof. R. NEWSTEAD, M.Sc., F.R.S.
Prof. J. W. W. STEPHENS, M.D.
EDWIN THOMPSON.

Representative of Students' Section :

Miss M. BOWEN, B.Sc.

REPORT of the COUNCIL.

During the Session 1919-20 there have been seven ordinary evening meetings. The field meeting was held on June 26th, when, in association with the Liverpool Geological Society, a large party visited Hilbre Island and spent a very successful afternoon.

The communications made to the Society at the ordinary meetings have been representative of many branches of Biology, and the various exhibitions and demonstrations thereon have been of the utmost interest and value.

The meeting on March 12th was a very special one. The Students' Section were the hosts of the senior branch, and the lecturer was Prof. W. J. Dakin, D.Sc., F.L.S., who gave an account of his work in Western Australia.

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance sheet are appended.

The members at present on the roll are as follows :—

Ordinary members	47
Associate members	14
Student members, including Students' Section about	30
Total	91

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the thirty-fourth session was held at the University, on Friday, October 10th, 1919.

The Retiring President (Prof. Ramsden) took the chair in the Zoology Theatre, during the earlier part of the proceedings.

1. The Report of the Council on the Session 1918-1919 (see "Proceedings," Vol. XXXIII, p. viii) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1918-1919 (see "Proceedings," Vol. XXXIII, p. xvi) was submitted and approved.

3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Prof. W. Ramsden, M.A., D.M., Prof. Herdman, D.Sc., F.R.S.; Hon. Treasurer, W. J. Halls; Hon. Librarian, May Allen, B.A.; Hon. Secretary, W. Rimmer Teare, A.C.P.; Council, R. C. Bisbee, M.Sc. (Mrs.), S. T. Burfield, B.A., R. Caton, M.D., F.R.C.P., J. A. Clubb, D.Sc., J. W. Cutmore, G. Ellison, E. L. Gleave, M.Sc. (Miss), J. Johnstone, D.Sc., W. S. Laverock, M.A., B.Sc., Prof. R. Newstead, M.Sc., F.R.S., Prof. J. W. W. Stephens, M.D., Edwin Thompson, C.C.

4. Hugh R. Rathbone, Esq., delivered the Presidential Address on "Wheat and its Pests" (see Transactions, p. 3). A vote of thanks proposed by the Vice-Chancellor, seconded by Prof. Herdman and supported by Prof. Newstead, was passed.

The second meeting of the thirty-fourth session was held at the University, on Friday, November 14th, 1918, Dr. Clubb presiding.

1. Prof. Herdman submitted the report which he had prepared for The Liverpool Marine Biology Committee and gave a summary of "The History and Work of the L.M.B.C." (see Transactions, p. 11).

The third meeting of the thirty-fourth session was held at the University, on Friday, December 12th, 1919. Prof. Herdman occupied the chair.

1. The Chairman exhibited and made remarks upon some examples of " Grain Pests " sent down from the British Museum.

2. Prof. Newstead and Capt. Noël Pillers, F.R.C.V.S. had prepared papers on some Forage and Parasitic Mites. Unfortunately the electric light failed at the outset of Capt. Pillers paper, and the reading was postponed to the next meeting.

The fourth meeting of the thirty-fourth session was held at the University, on Friday, January 9th, 1920, Prof. Herdman presiding.

1. Capt. Noël Pillars resumed his address on " Some Parasitic Mites (Acarina).

Amongst the speakers following was Prof. Dakin, of the University of Western Australia, who was home on leave.

The fifth meeting of the thirty-fourth session was held at the University, on Friday, February 13th, 1920. The President in the chair.

1. Mr. S. Burfield, B.A. exhibited specimens and read a paper on "The Hand Skeleton of some Cetacean Foetuses" (see Transactions, p. 93).

2. Dr. Johnstone submitted the Annual Report of the Investigations carried on during 1919 in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 97) and added an account of various experiments in connection with the migration of fish in local waters.

The sixth meeting of the thirty-fourth session was held at the University, on Friday, March 12th, 1920, in conjunction with the Students' Branch, the President of which, Mr. I. G. Hamilton, occupied the chair.

1. Prof. W. J. Dakin gave a highly interesting account of his experiences as a "Biologist in Western Australia."

At the conclusion a hearty vote of thanks was accorded the lecturer on the motion of Prof. Doncaster, seconded by Mr. G. F. Sleggs and supported by Dr. Tattersall of Manchester University Museum. Following the lecture the senior branch, by invitation of the Students, joined them in a social gathering.

The seventh meeting of the thirty-fourth session was held at the University, on Friday, May 14th, 1920, Prof. Herdman presiding.

A number of miscellaneous communications were presented as follows :—

1. Mr. H. F. Carter and Dr. B. Blacklock : " The Rot-hole breeding Mosquito."

2. Miss A. M. Evans : " The Plague Flea."

3. Prof. R. Newstead : " A wind-borne Coccid."

4. Mr. T. Southwell : " Parasites of the Zebra, N.E. Rhodesia, etc."

5. Mr. J. Ronald Bruce : " Various exhibits from the Forest-bed at Meols."

6. Mr. S. T. Burfield : " Various marine animals."

7. Prof. W. A. Herdman : " 'Ginger-beer plant' or 'Californian bees.' "

The eighth meeting of the thirty-third session was held on Saturday, June 26th. A visit to Hilbre Island had been arranged in conjunction with the Liverpool Geological Society. A large party took advantage of a fine afternoon, and a very enjoyable time was spent on and about the Island.

A short business meeting was held, and, on the motion of Prof. Herdman, Prof. P. G. H. Boswell was unanimously elected President for the ensuing session. Dr. Clubb was appointed delegate of the Society to the British Association Meeting at Cardiff.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1919-1920.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1908 Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.

1919 Adami, Dr. J. G., F.R.S., Vice-Chancellor, The University, Liverpool.

1909 *Allen, May, B.A., Hon. Librarian, University, Liverpool.

1918 Baldwin, Mrs., M.Sc., Zoology Dept., University, Liverpool.

1913 Beattie, Prof. J. M., M.A., M.D., The University, Liverpool.

1903 Booth, Chas., Cunard Building, Liverpool.

1919 Boswell, Prof., P. G. H., The University, Liverpool.

1912 Burfield, S. T., B.A., Zoology Department, University, Liverpool.

1886 Caton, R., M.D., F.R.C.P., 7, Sunny Side, Prince's Park, Liverpool.

1886 Clubb, J. A., D.Sc., Free Public Museums, Liverpool.

1916 Dale, Sir Alfred, The University, Liverpool.

1919 Doncaster, Prof. L., F.R.S., The University, Liverpool.

1917 Duvall, Miss H. M., B.Sc., Zoology Department, University, Liverpool.

1910 Ellison, George, 52, Serpentine Road, Wallasey.

1902 Glynn, Prof. Ernest, 67, Rodney Street.

1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.

1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton.

1886 Herdman, Prof. W. A., D.Sc., F.R.S., Vice-President, University, Liverpool.

1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.

1912 Hobhouse, J. R., 54, Ullet Road, Liverpool.

1902 Holt, Dr. A., Rocklands, Thornton Hough, Cheshire.

1903 Holt, Richard D., India Buildings, Liverpool.

1898 Johnstone, Prof. James, D.Sc., University, Liverpool.

1918 Jones, Philip, "Brantwood," St. Domingo Grove, Liverpool.

1896 Laverock, W. S., M.A., B.Sc., Free Public Museums, Liverpool.

1915 Macdonald, Prof. J. S., B.A., F.R.S., The University, Liverpool.

1917 Milton, J. H., F.G.S., Merchant Taylors' School, Great Crosby.

1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.

1913 Pallis, Mark, Tätoi, Aigburth Drive, Liverpool.

1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.

1915 Prof. W. Ramsden, Vice-President, University, Liverpool.

1903 Rathbone, Hugh R., M.A., J.P., President, Greenbank, Liverpool.

1890 *Rathbone, Miss May, Backwood, Neston.

1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.

1908 Share-Jones, J., D.Sc., F.R.C.V.S., University, Liverpool.

1886 Smith, Andrew T., "Solna," Croxteth Drive, Liverpool.

1920 Southwell, T., School of Tropical Medicine, University, Liverpool.

1903 Stapledon, W. C., "Annery," Caldy, West Kirby.

1913 Stephens, Prof. J. W. W., M.D., University, Liverpool.

1915 Teare, W. Rimmer, A.C.P., Hon. Secretary, 12, Bentley Road, Birkenhead.

1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.

1905 Thompson, Edwin, "Woodlands," 13, Fulwood Park, Liverpool.

1889 Thornely, Miss L. R., Hawkshead, Ambleside.

1888 Toll, J. M., 49, Newsham Drive, Liverpool.

1920 Walker, Dr. C., The University, Liverpool.

1918 Whitley, Edward, Bio-Chemical Laboratory, University.

1920 Yorke, Prof. Warrington, M.D., School of Tropical Medicine, University, Liverpool.

B. Associate Members.

1916 Atkin, Miss D., High School for Girls, Aigburth Vale, Liverpool.

1915 Bisbee, Mrs., M.Sc., Zoology Department, The University, Liverpool.

1905 Carstairs, Miss, 39, Lilley Road, Fairfield.

1914 Cutmore, J. W., Free Public Museums, Liverpool.

1918 Evans, Miss Alwyn M., M.Sc., School of Tropical Medicine, University, Liverpool.

1916 Gleave, Miss E. L., M.Sc., Oulton Secondary School, Clarence Street, Liverpool.

1905 Harrison, Oulton, 3, Montpellier Crescent, New Brighton.

1920 Kewley, Miss Helen C., Gothic Lodge, Park Road S., Birkenhead.

1920 Malpas, A. H., The Public Museums, Liverpool.

1919 Mayne, Miss C., B.Sc., 17, Laburnum Road, Fairfield.

1919 Sleggs, G. F., B.Sc., Zoology Dept., University, Liverpool.

1915 Stafford, Miss C. M. P., B.Sc., 312, Hawthorne Road, Bootle.

1917 Swift, Miss F., B.Sc., Queen Mary High School, Anfield.

1912 Wilson, Mrs. Gordon, High Schools for Girls, Aigburth Vale, Liverpool.

C. University Students' Section.

President: Miss M. Bowen, B.Sc.

Secretary: Miss Laura Thorpe, B.Sc.

(Contains about 30 members.)

D. Honorary Members.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du Trocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Cr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. **Dr.**

1919, Oct. 1st to Sept. 30th, 1920.	£	s.	d.
By Balance from last Session	55	17	10
,, Subscriptions	16	16	0
,, ,, (in Arrears)	1	1	0
,, ,, (in Advance)	1	1	0
,, ,, (Associates)	2	2	0
,, Sale of Volumes	45	15	6
,, Interest from Investment	2	12	6
,, Bank Interest	1	3	7
	£126	9	5

1919, Oct. 1st to Sept. 30th, 1920.	£	s.	d.
To Teas and Postages last Session	3	4	0
,, Insurance of Library	2	4	0
,, Messrs. Tinling & Co.	52	11	6
,, Tea A/c	2	18	0
,, Postages	3	8	0
,, Hon. Secretary's Expenses	1	2	1
,, Balance in Bank	56	16	7
,, Cash in hand	4	5	3
	£126	9	5

INVESTMENT :—

5 % War Loan £113 11 1

Audited and found correct,

JOSEPH A. CLUBB.

LIVERPOOL, *September 30th, 1920.*

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

PRESIDENTIAL ADDRESS
ON
WHEAT AND ITS PESTS.

By Hugh R. Rathbone, M.A., J.P.,
Member of the Royal Commission on Wheat Supplies.

[Delivered October 10th, 1919.]

Early in the War I realised that much time was being spent by the Grain Pests Committee of the Royal Society and other scientific bodies in examining the problems of wheat pests, from the point of view of the preservation of wheat for lengthy periods. As a wheat merchant, that difficulty had never seriously presented itself to me, because wheat merchants as a rule do not want to keep actual wheat; they like to pass it on to someone else as soon as they can. They have found by long and painful experience that the undue keeping of wheat is an expensive amusement, not so much because it decreases in volume by reason of pest ravages, but because it is generally found that the heavy cost of keeping it is rarely made up by the realization of the wheat when it finally finds its way to the mill. Wheat eats money, rather than is eaten by pests, and certainly cannot be classed with port which if good in the first place always makes 5 per cent. per annum.

But the War modified many of our views and the wheat merchant no longer looked askance at wheat in store. The charges were looked upon as a light form of insurance and it was realised that a contract of wheat to be shipped or even a bill of lading of wheat actually shipped, were only too often "Scraps of Paper" owing to the activity of the submarine. And so the corn trade no longer looked with amused interest at the researches of scientific men into the habits and customs of such animals as are usually associated with wheat.

Weevils.—Weevils loomed very large in the scientific mind, and certainly in one country they became a very real and big problem, but except as regards Australia I cannot say that they ever gave us any real trouble even in such cases as those where we, or the Royal Commission, had kept stores of wheat against possible serious submarine trouble. I will return later to the Australian problem.

Mites.—The little beast that did give us some trouble was the mite. The mite was previously well known to the grain merchant but had never been regarded as a cause for worry. A mitey condition in fact was generally looked upon as rather a help in selling the wheat: a good judge of wheat told me years ago, "never be afraid of mitey wheat, it only shows how good and rich it is." But the War modified even this view. The Canadian crop of wheat of 1915 which was one of the finest ever gathered in that country was a good deal more subject to this pest than we altogether appreciated. The weather had been absolutely perfect during the growing and gathering of this particular crop, the berry was more than usually big and well filled, the wheat was indeed too rich for keeping purposes. Farmers and others often abuse cold and wet and stormy weather, but the fact is that wheat, like man, is strengthened by adversity, and is in fact "made strong and brave by perpetual pain, and a life-long struggle with wind and rain." I won't say that the 1915 Manitoba crop was unable to resist the mite; I would rather put it in the other way, the mite was unable to resist the deliciously sweet and well-filled berry. But it must not be imagined that the mite eats the wheat up rapidly; it is not for what it eats that it becomes a nuisance, but its presence, when in large numbers, is stimulated by climatic conditions, specially warm muggy weather, generates heat, and when the wheat gets above a very moderate temperature it very quickly gets out of condition, has to be turned and blown and taken journeys along bands

and sieved and screened, and if it is still warm and cannot be disposed of it must be sacked. This generally gets over most troubles. Mites, it is interesting to note, are hardly ever known in winter wheat, i.e., wheat sown in the winter.

Grubs and Rodents.—Grubs are almost unknown to the wheat merchant. When wheat is once threshed and kept in modern granaries, Bishop Hatto's experiences also are unknown. Stored, as many thousands, not to say millions, of quarters were stored in the open in Australia, the ravages of mice and rats were quite considerable, but we never had any such experience at home.

Grasshoppers.—The grasshopper or locust is still a problem in some of the great wheat-growing countries, specially in the Argentine but it is rapidly disappearing before the advance of civilisation

Black Rust.—Perhaps the most serious pest is what we call black rust—this is, I believe, a small fungus probably dormant in many kinds of wheat, which only becomes active under certain climatic conditions. It occurs generally only where there has been a long period of wet weather after the wheat has got to the milky stage, and when it ought to be ripening, which wet weather is succeeded by abnormally hot weather, when the temperature rises possibly to 90 degrees. The mischief appears to be very rapidly done, and in 48 hours it would seem that the soft inside of the berry is turned into a black and somewhat slimy substance. Black rust, as far as I know, is only found in any quantity in spring wheat, i.e., sown in spring; but that may be only because climatic conditions synchronise with the ripening of spring wheat.

But to return to the weevil and Australia. In passing I may add that the weevil in India has, in its time, managed to dispose of quite appreciable quantities of wheat. This is probably due to the primitive way in which the Indian farmers store their wheat. The crop of wheat is gathered in India in

March and such wheat as is not sold, or at any rate bagged, by the time the monsoon bursts, is "pitted" to protect it from the heavy rains. Big holes are dug in the ground and the wheat is buried till the rains are over. Not infrequently the farmer elects to hoard his wheat which is pitted just as the native hoards silver, and it may remain in the pit for many months or even several years.

But even with these untoward conditions the amount of Indian wheat that is lost by the weevil ravage is negligible, and I suppose I am probably overstating the loss of wheat all over the world consumed by weevil if I put it at 0.001 per cent. per annum. The only trouble the weevil has given us is the same as in the case of the mite ; if he turns up in rather large numbers and temperature is such that he ceases to be comatose, and becomes active, he generates heat, and thus brings up the temperature of the wheat and causes the trouble, and the wheat has to be blown and screened.

The wheat crop of Australia gathered in 1915 was an abnormally big one, more than twice as big as any previous crop ; this was partly due to the guarantee given the farmer as to price and the consequent large acreage and partly to very favourable growing and harvesting weather.

Owing to shortness of shipping no serious attempt was made to deal with this wheat until October, 1916, nearly twelve months after the crop had been harvested, when the British Government made a contract with the Australian Government for 500,000 tons, subsequently increased, after the Wheat Commission was set up, to 3,500,000 tons. A very considerable amount of this was shipped in the first months of 1917, after shipping had been commandeered. But after March of that year it was only possible to ship small monthly parcels owing to the great shortness of shipping due to submarine action and the very long voyage to Australia compared with that to North America. The last portion of this purchase is only now being got away from Australia.

Sensational reports have appeared occasionally in the papers about the severe losses incurred by the Government in purchasing a much larger amount of wheat in Australia than they were at all likely to be able to ship. This was hardly the case ; the intensive submarine action had not begun when purchases were made in October and November, 1916. It was hoped when the Royal Commission was set up that the bulk of that large purchase would be shipped in twelve months. The price paid the Australian Government compared very favourably with that paid to the United States of America, and even allowing for loss of interest, cost of holding, and loss by weevil, etc., the purchase has proved an excellent one for the British Exchequer, and incidently helped Australia to preserve her financial stability. The loss that the British Government will be called upon to bear will be small, certainly less than 2 per cent. The smallness of the loss will be found to be largely due to the measures initiated by the Royal Commission to combat the evil.

Early in the spring of 1917, when it was found that the wheat could not be shipped as rapidly as it had been hoped, Professor Maxwell Lefroy was asked to go out to Australia to report on what he recommended should be done after studying the problem on the spot. He went first to the United States of America to glean any information possible there. The Royal Commission also sent out a first-class commercial representative, Mr. R. A. Love, to deal with any business problems that might arise.

The results of their investigations proved eminently successful. Professor Lefroy's methods of treating the infested grain were :—

(1) To temporarily seal up the more heavily infested lots with a covering of malthoid and to pump in CO_2. The wheat was then left until such time as it could be more effectively dealt with by

(2) Passing it through a heated sterilizing chamber at a temperature of 140-145° F.

The first method was adopted in order to temporarily check the ravages of the insects until such time as the combined cleaning and sterilizing plant could be erected. The standard plant finally erected for sterilizing the wheat is also provided with four sets of pre-cleaning machines (in one instance three sets only were used) of a special and patented design, the latter so arranged as to effectively separate loose weevil, "pollard" and other offal from the wheat. Special screens are also provided for separating weevil dust ("frass") which is collected and delivered into bags at the side of the machine. After this treatment the wheat is delivered on to special "jig" screens and subjected to strong aspiration, thereby further cleaning the wheat and separating more offal therefrom, the material thus separated being collected automatically.

After this preliminary cleaning the wheat is delivered into an elevator which in turn delivers it to the sterilizer; the latter being of rectangular design, with numerous steam coils, so spaced as to impart the desired temperature of 140-145° F. to the wheat. The wheat surrounds the steam coils, and by means of a mechanically operated reciprocating cut-off device at the bottom of the sterilizer, the flow of wheat past the coils can be accurately regulated; the steam pressure in the coils is also kept constant by means of a reducing valve, ensuring an even temperature and preventing over-heating, and vortexing cannot take place. The time taken in passing the grain through the sterilizer occupies from three to four minutes. The condensed water from the coils is drawn off through a steam trap, the hot water being delivered to the hot water tank for the boiler feed.

The wheat after passing through the sterilizer is delivered on to a long spiral conveyor, which is fitted with suitable gear, enabling it to be reversed when desired, as when starting up the sterilizer the wheat is re-delivered to the elevator and circulated until the desired temperature is reached, after

which the long spiral is rotated in the correct direction for working, the wheat being delivered along its full length to the receiving boot of the elevator, and also to the separators.

The separators consist of two sets of jig screens, each set having upper and lower screens, the upper being fitted with coarse screen plates, removing "white-heads" and large particles, the whole grains passing through. The lower screen plates are of fine mesh, removing weevil dust, dead weevils, and small screenings; the whole grain tailing over the end. The separators are also provided with aspiration on both inlet and outlet ends, all light material being thereby drawn off and collected in a cyclone collector.

The sterilized and cleaned grain is then delivered into an elevator, which in turn passes it to the silo where it is bagged off and delivered to the trucks. The bagging off floor is placed at a convenient height above the rail level to allow of shooting into the trucks below.

The boiler is provided for supplying steam to the sterilizer and also to the engine for driving the plant. The boilers have a capacity of from 3,000 to 4,000 lbs. steam per hour at 100 lbs. steam pressure; suitable hot and cold water tanks with feed pump and injector are provided for feed purposes.

The engines are of the long-stroke, slow-speed, horizontal type, arranged to drive through belt drive. The whole of the plant is housed in a building of substantial design, the floor being concreted throughout to facilitate cleaning and to reduce the risk of fire.

The plant is capable of treating 1,000 bushels per hour, or approximaetly 2,500 bags per shift of eight hours. The work is carried on in three shifts on many of the plants. Up to the present about 500,000 tons of wheat have been sterilized, and the probabilities are that half as much again has been dealt with by the various States in Australia.

All the weevils, together with their eggs and larvæ, are

killed in passing through the sterilizer; and from 200 to 300 lbs. weight of dead weevils are secured from the total amount of wheat (2,500 bags) treated during a single shift of eight hours; and as it is estimated that there are about 442,000 weevils to the lb. the grand total is immense; but happily the insects can no longer continue their trade of levying tribute as the sterilizer has done its work so thoroughly.

Neither the treatment with CO_2 nor the sterilizing process impairs the food value or the gluten properties of the wheat in any way; and the sterilized grain, when properly stacked and housed, remains free from fresh attacks for many months, approximately 9 to 12.

The weevils which are most destructive and troublesome are (1) *Rhizopertha dominica;* (2) *Calandra granaria;* and (3) *C. oryzæ.* The first is very destructive and troublesome and at times it flies in millions; the second does the most damage but being unable to fly is more easily controlled than is *Calandra oryzæ.* Many million bushels of wheat have been destroyed by these insects in Australia; but it must be remembered that the conditions under which that enormous bulk of wheat remained stored for some years in Australia were quite exceptional, and are very unlikely ever to occur again.

THE

MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

THIRTY-THIRD ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

By Professor W. A. Herdman, F.R.S.

This is the final Report of the Liverpool Marine Biology Committee; but not, it is hoped, of the Port Erin Biological Station and the work in marine biology and fisheries research which has been carried on during the past thirty-five years in the Liverpool district. As a consequence of the establishment of a department and endowed Chair of Oceanography in the University of Liverpool the Committee has decided to transfer its work, responsibilities and assets to that department of the University as from December 31st, 1919.* This does not mean that any change—save happily for the better—need be made in the direction or the conduct of the scientific work. The establishment of the Professorship of Oceanography in the University is intended to consolidate and perpetuate the local marine biological and other oceanographic investigations and their application to sea-fisheries research. The Council of the University has invited me to occupy the Chair of Oceanography for the first year, from October, 1919, after which period of reconstruction and arrangement I shall gladly resign the Professorship into the competent hands of my colleague, Dr. James Johnstone, who has for so many years been associated with the scientific work of the Lancashire Sea-Fisheries. It is the earnest hope of the founders of the Chair that the work

* The minutes of the Meeting of the Committee at which this important decision was arrived at will be found in the Treasurer's Report on p. 87

of the Port Erin Biological Station and the scientific investigations of the Lancashire and Western Sea-Fisheries Committee may for the future be united under the Oceanographic Department of the University, and that this union may conduce to the advancement of our knowledge of the sea and its products, and the promotion of the local fishing industries.

The recovery in numbers at the Biological Station is remarkable. In 1914, we recorded ninety researchers and students occupying work-places in the laboratory and 12,000 visitors to the Aquarium. In 1918 we had 16 workers in the laboratory and over 7,600 visitors to the Aquarium. This year (1919) the Curator's report shows over 60 laboratory workers and over 23,000 visitors—a number far beyond our highest pre-war record of 16,000.

The work of the staff at the Biological Station has been carried on as usual, and large collections of the plankton in the bay have been made throughout the year.

As on previous occasions the statistics as to the use made of the institution throughout the year will be given in the form of a "Curator's Report" (see below).

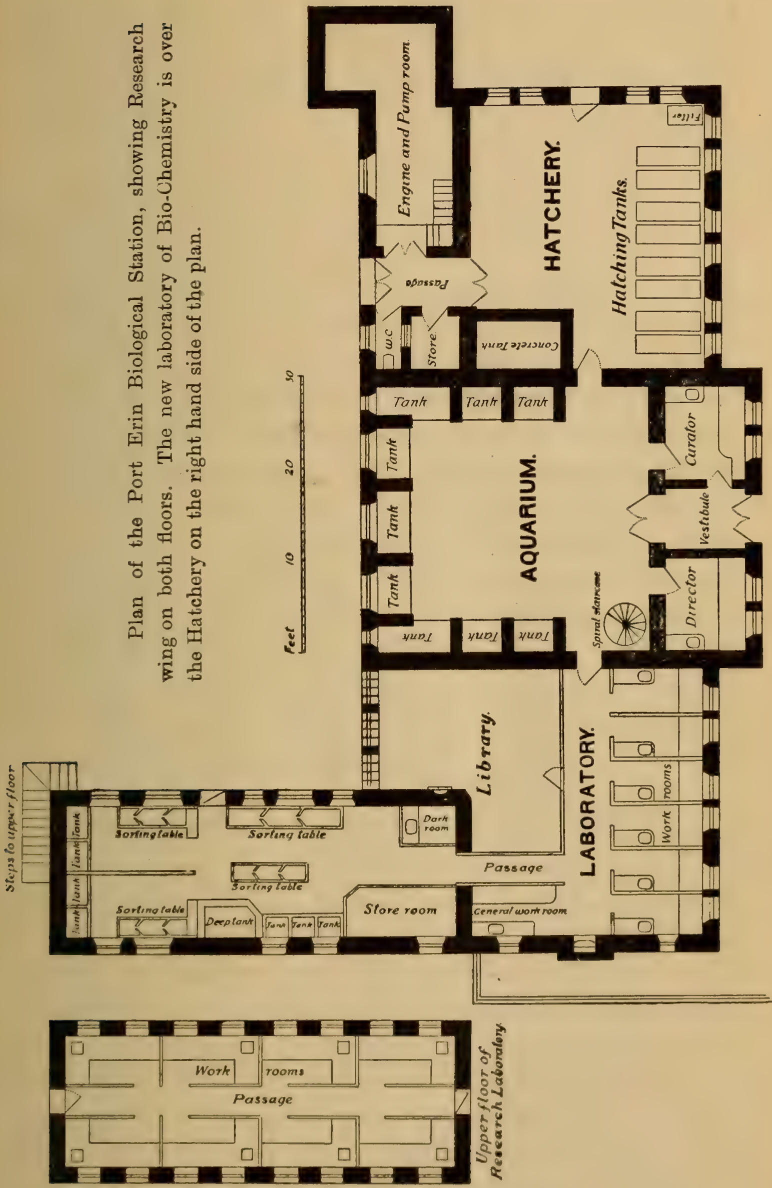
It may be useful to those proposing to work at the Biological Station that the ground plan of the buildings, showing the laboratory and other accommodation, should be inserted in this Report as on previous occasions (see p. 13).

Curator's Report.

Mr. Chadwick reports to me as follows on the various departments of the work at the Station during 1919 :—

Station Record.

"Sixty-six workers occupied our laboratories during the past year, the majority being undergraduates from the Departments of Zoology and Botany of the University of Liverpool. The University of Manchester and University College, Reading,



Plan of the Port Erin Biological Station, showing Research wing on both floors. The new laboratory of Bio-Chemistry is over the Hatchery on the right hand side of the plan.

also sent contingents ; and in the daily round of shore collecting, tow-netting and microscopical examination in the laboratory much good work was done during the Easter vacation, under the direction of Professor Herdman, Miss R. C. Bamber and Miss Blackwell.

" An important research into the seasonal variation in the alkalinity of sea-water was conducted by Professor B. Moore, who with his son, Mr. T. Moore, Mr. E. Whitley and Mr. T. A. Webster occupied the bio-chemical laboratory during the Easter vacation. They were followed in the work by Dr. G. B. R. Prideaux of University College, Nottingham, and the research was resumed and carried on for a fortnight in July by Mr. T. Moore and Mr. Webster. During the latter part of the Easter vacation Miss C. Mayne resumed her work on the animal ecology of Port Erin Bay ; and in July Mr. G. F. Sleggs, who succeeded Miss Mayne as Edward Forbes Exhibitioner, spent a fortnight in observing the habits and preserving specimens of the common barnacle, *Balanus balanoides*, with a view to the authorship of an L.M.B.C. Memoir upon that type. During the summer vacation Miss E. C. Herdman, of Newnham College, Cambridge, re-discovered the interesting Orthonectid *Rhopalura giardii* which occurs as a parasite in the body cavity of the brittle-starfish *Amphiura elegans*, and devoted much time and labour to the elucidation of its structure. At the same time Dr. H. E. Roaf occupied the bio-chemical laboratory and devoted himself to research on the CO_2 in sea-water under different conditions.

" Amongst a considerable number of anemones brought in by several fishermen from the local fishing grounds was one which was immediately recognised as probably new to our fauna. It had, unfortunately, been injured, probably by a fish-hook, and survived only a few days. Mr. T. A. Stephenson of University College, Aberystwyth, to whom it was sent, identified it as *Ilyanthus mitchellii*, a species not hitherto

known to occur in the L.M.B.C. District. During a brief visit to Port Erin in September Mr. Stephenson detected on a water-worn stone brought in by a fisherman a few specimens of one of the smallest British anemones, *Edwardsia carnea.* This species was first recorded as a member of the marine fauna of the Isle of Man in 1906, but the specimens under notice are the only ones seen since that year.

"On August 27th a young grey seal (*Phoca vitulina*) was captured on the beach by one of the local fishermen and presented by him to the Institution. It measured 2 feet 10 inches over all. Placed in the large concrete tank in the Hatchery it attracted much attention. It was believed to have been thrown ashore by the waves during the prevalence of a summer storm in the early hours of the morning, and it is probable that it sustained some injury, for it survived capture only two days.

"A specimen of the nurse hound or large-spotted dog-fish (*Scyllium catulus*) measuring 3 feet 6 inches in length and weighing 12 lbs. was brought in alive on March 1st and lived a few days in one of our tanks. The occurrence of this fish in Manx waters has been previously recorded, but it is by no means common. Some of the Port Erin fishermen said they had not previously seen one. About the same time a lamprey (*Petromyzon marinus*) about 10 inches long was brought in. The fisherman who captured it said that while hauling one of his long lines he found it devouring a cod. The lamprey is another well-known fish the occurrence of which in Manx waters is rare.

List of Workers 1919.

Dec. 20*th*, 1918, *to Jan.* 2*nd*, 1919.
Professor Herdman.
Miss E. C. Herdman.

March 22*nd to April* 19*th*.
Professor Herdman.
Miss E. C. Herdman.
Miss R. H. Barker.

March 25*th to April* 7*th*.
Professor B. Moore.
Mr. T. Moore.
Mr. E. Whitley.
Mr. T. A. Webster.

March 26th to April 15th.
Professor F. J. Cole.
Miss N. B. Eales.
Mr. A. S. Wright.
Miss D. Freeman.
Miss G. M. Redfern.
Miss Trewavas.

March 30th to April 1st.
Dr. J. Johnstone.

March 31st to April 22nd.
Miss L. Thorpe.
Miss K. Berry.
Miss A. E. Chesters.
Miss O. Bangham.
Miss M. Bowen.
Miss R. C. Bamber.
Mr. G. F. Sleggs.
Miss B. E. Gilman.
Miss M. Hobbins.

April 4th to 10th.
Dr. G. B. R. Prideaux.

April 5th to 14th.
Dr. J. Stuart Thomson.
Miss E. Vernon.
Miss C. Rogers.
Miss E. Comstive.
Miss E. McGill.
Miss A. Dixon.
Miss M. Dixon.
Mrs. Baker

April 7th to 9th.
Miss M. Knight.

April 7th to 21st.
Miss E. M. Blackwell.
Miss R. Robbins.
Miss C. Mayne.
Miss M. A. Battersby.
Miss B. M. Baggs.
Miss G. Rutherford.
Miss E. A. Dodd.
Miss C. M. Jarvis.
Miss D. M. Atkin.
Miss H. Clarke.

April 12th to 19th.
Miss M. Critchley.
Miss K. Murray.
Miss A. Swindells.
Miss B. Atherton.
Miss E. Lewis.
Miss E. M. E. Gardiner.
Miss M. A. Pyke.
Miss D. Hookins.
Mr. J. G. Hamilton.

April 12th to 23rd.
Miss G. J. Stoddart.
Miss K. M. Stoddart.
Miss D. Stephenson.
Miss M. Holden.

April 14th to 30th.
Miss J. Graham.
Miss M. Simpson.
Miss J. Hilton.
Miss W. Kehoe.
Mr. R. W. Jones.
Miss E. L. Gleave.

April 25th to May 9th.
Dr. W. M. and Mrs. Tattersall.

July 7th to 21st.
Mr. T. Moore.
Mr. T. A. Webster.

July 11th to 23rd.
Mr. G. F. Sleggs.

July 14th to 30th.
Miss E. Vernon.

July 16th to September 28th
Professor Herdman.
Miss E. C. Herdman.

July 30th to September 3rd.
Dr. H. E. Roaf.

September 3rd to 9th.
Mr. T. A. Stephenson.

Oct. 8th to 13th and Dec. 5th to 11th.
Miss M. Knight.

The Fish Hatchery.

"The stock of spawners which furnished the eggs hatched during the season of 1919 consisted of 62 survivors of the previous year's stock and 113 fish purchased from local fishermen, as they were caught, off Niarbyl, in September and October, 1918, making a total of 175 fish. Some loss occurred at the end of the year, probably owing to temporary failure

of the supply of mussels for food, and the number of fish available at the beginning of the hatching season is not exactly known.

"The first fertilised eggs, about 5,000 in number, were placed in the hatching boxes on February 26th, and the last on May 9th. The ponds were skimmed on 32 days. The numbers of eggs were comparatively small throughout the season, exceeding 100,000 on 11 days only. The total number of fertilised eggs obtained was 2,949,000 and of larvæ set free 2,428,450. The cold and inclement weather of February and March, and the loss of spawners above alluded to were probably causes of the reduced numbers of eggs. It is possible, too, that reduced fecundity of the fish of the old stock may have contributed.

"The Hatchery Record, giving the number of eggs collected and of larvæ set free on the various days, is as follows:—

Eggs collected.	Date.	Larvae set free.	Date.
59,850	... Feb. 26 to March 3	53,650	... March 24
210,000	... March 5 to 15	118,650	... April 1
157,500	... " 17 to 24	140,700	... " 7
72,000	... " 26	65,700	... " 12
287,700	... " 31 and April 1	260,100	... " 17
226,800	... April 2 and 3	211,450	... " 21
535,500	... " 4 to 7	453,600	... " 24
312,900	... " 8 to 11	271,950	... " 30
268,800	... " 12 and 14	236,250	... May 2
415,800	... " 17 and 19	319,200	... " 5
273,000	... " 21 to 25	216,300	... " 8
129,150	... " 30 to May 9	80,800	... " 15
2,949,000	Total eggs.	2,428,350	Total larvae.

Lobster Culture.

"The supply of berried female lobsters with nearly ripe eggs during the past season was again disappointing, only fifteen being brought in, against 27 obtained during the corresponding period in 1918. These yielded a total of 9,702 larvæ,

or an average number of 646 per lobster. This also compares unfavourably with the average of 1,223 yielded by the spawners last year. Of the total number of larvæ 9,050 were set free in the first stage, the number of rearing jars being still inadequate. The balance of 652 were placed in the rearing jars and fed exclusively on plankton. One hundred and seventy-two—or slightly more than 1 in 4—were successfully reared to the lobsterling stage and set free.

The Aquarium.

"The Aquarium has again shared the returning prosperity of the Isle of Man, 23,622 visitors having been admitted during the past year. Every effort was made to make the tanks as attractive as possible. The display of sea-anemones was larger and more varied than ever before, and attracted a large share of attention on the part of the more intelligent visitors. The third edition of the Guide to the Aquarium was exhausted before the end of the season, 1,666 copies having been sold.

(Signed) H. C. Chadwick."

Report of the Edward Forbes Exhibitioner.

An "Edward Forbes Exhibition" was founded* in 1915, at the University of Liverpool, in commemoration of the pioneer marine biological work done in this district by the celebrated Manx naturalist, who was born about a hundred years ago. The object of the Exhibition is to enable some post-graduate student of the University to proceed to the Port Erin Biological Station for the purpose of carrying on some piece of biological research, more or less in continuation of the line of work opened up by Forbes, or an investigation which has grown out of such work.

The Edward Forbes Exhibitioner for the year 1919 is

* The Regulations in regard to the Exhibition will be found at p. 85.

George Frederick Sleggs, B.Sc., who spent a couple of weeks at Port Erin in April and again in July working at the structure, occurrence and habits of the living rock-barnacle *Balanus balanoides*. Mr. Sleggs has submitted to me a detailed report upon his work at Port Erin, but in view of the facts that (1) so far he has been engaged mainly on testing and verifying the results of previous observers, and that (2) the L.M.B.C. Memoir upon which he is now at work will, it is hoped, soon be ready for publication, it seems unnecessary to print anything further here.

L.M.B.C. Memoirs.

Since our last report was published, no further Memoirs have been issued to the public. Himanthalia, by Miss L. G. Nash, M.Sc., is ready to print; Miss E. L. Gleave, M.Sc., has nearly completed her Memoir on Doris, the Sea-lemon; Mr. Burfield, is writing the Memoir on Sagitta; Mrs. Bisbee has made further progress with Tubularia, and still other Memoirs are in preparation.

The following shows a list of the Memoirs already published or arranged for:

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.
II. Cardium, J. Johnstone, 92 pp., 7 Pls.
III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.
IV. Codium, R. J. H. Gibson and H. Auld, 3 Pls.
V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.
VI. Lepeophtheirus and Lernæa, A. Scott, 5 Pls.
VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.
VIII. Plaice, F. J. Cole and J. Johnstone, 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.
XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 144 pp., 9 Pls.

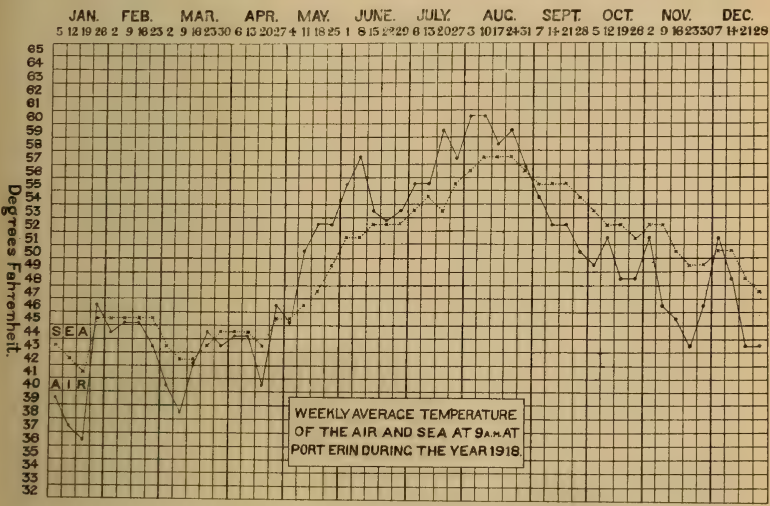
XVIII. Eledone, A. Isgrove, 113 pp., 10 Pls.
XIX. Polychaet Larvæ, F. H. Gravely, 87 pp., 4 Pls.
XX. Buccinum, W. J. Dakin, 123 pp., 8 Pls.
XXI. Eupagurus, H. G. Jackson, 88 pp., 6 Pls.
XXII. Echinoderm Larvæ, H. C. Chadwick, 40 pp., 9 Pls
XXIII. Tubifex, G. C. Dixon, 100 pp., 7 Pls.
Himanthalia, L. G. Nash.
Doris, E. L. Gleave.
Tubularia, R. C. Bisbee.
Aplysia, N. B. Eales.
Terebella, C. P. M. Stafford.
Balanus, G. F. Sleggs.
Sagitta, S. T. Burfield.
Actinia, J. A. Clubb.
Zostera, R. Robbins.
Halichondria and Sycon, A. Dendy.
Oyster, W. A. Herdman and J. T. Jenkins.
Sabellaria, A. T. Watson.
Ostracod (Cythere), A. Scott.
Asterias, H. C. Chadwick.
Botrylloides, W. A. Herdman.

In addition to these, it is hoped that other Memoirs will be arranged for, on suitable types, such as *Pontobdella*, a Cestode and a Nematode.

As the result of a slight fire in the Zoology Department of the University, a portion of the stock of L.M.B.C. Memoirs has been partially destroyed. There are a certain number of damaged copies of some of the Memoirs which are stained or singed externally, but are still quite usable, and are suitable for laboratory work. The Committee has decided to offer these at prices ranging according to the condition from one-half to one-fourth of the published prices, as follows:—Memoir I., Ascidia, 6d. to 9d.; VI., Lepeophtheirus and Lernæa, 6d. to 1s.; VII., Lineus, 6d. to 1s.; XIII., Anurida, 1s. to 2s.; XIV., Ligia, 6d. to 1s.; XV., Antedon, 6d. to 1s. 3d.

Orders for these damaged copies should be sent to Professor Herdman, the University, Liverpool. New copies of any of the Memoirs should be ordered from the University Press, Liverpool.

The diagram of sea and air temperatures for 1919, compiled by Mr. Chadwick from his daily records, is not yet completed; but that for the preceding year, 1918, is inserted here as usual.



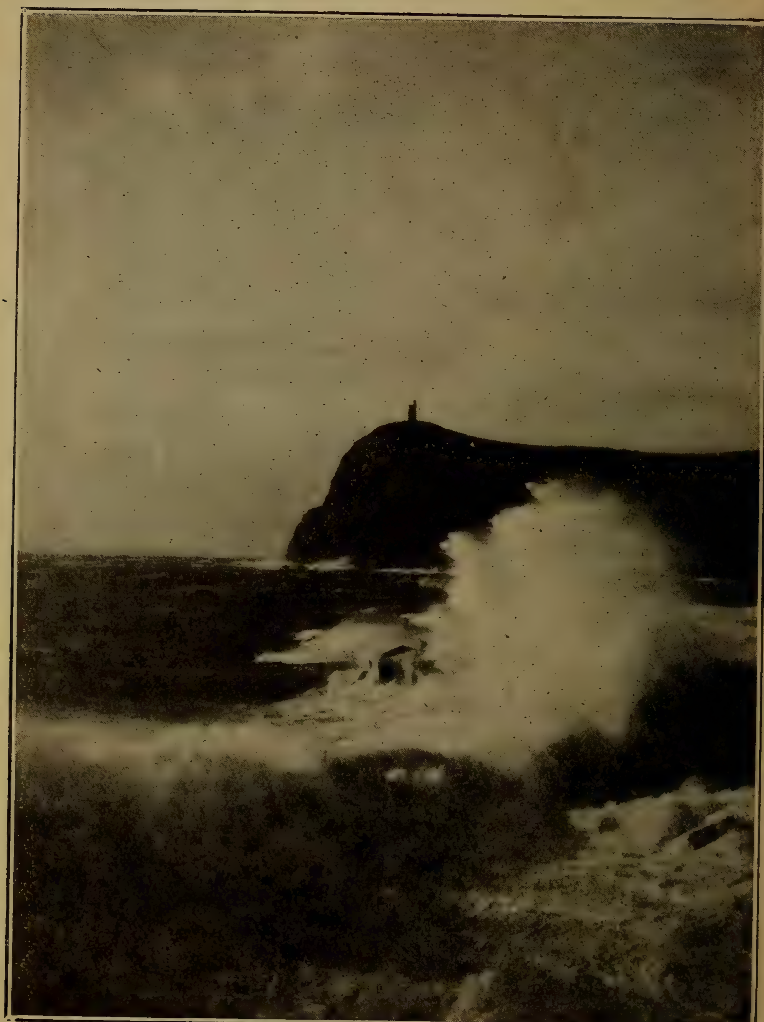
Appended to this Report are :—

(A). A short summary of the history and work of the Liverpool Marine Biology Committee.

(B) List of additions to the fauna and flora since 1896.

(C) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations—with Memoranda for the use of students, and the Regulations in regard to the "Edward Forbes Exhibition" at the University of Liverpool;

(D) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet for the year.



IN FRONT OF THE BIOLOGICAL STATION, PORT ERIN, IN A STORM.

[*From a photograph by Mr. Edwin Thompson.*

Appendix A.

SUMMARY OF THE HISTORY AND WORK OF THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Drawn up by W. A. Herdman.

Liverpool, 1885-1919.
Puffin Island, 1887-1892.
Port Erin, 1892-1919.

The Liverpool Marine Biology Committee was founded at a public meeting held on March 14th, 1885, in the Zoological Laboratory of University College, Liverpool, and attended by representatives of the scientific societies and museums of Liverpool, Manchester and Chester, and by other local naturalists. It was unanimously resolved that a committee be formed to investigate the Marine Biology of Liverpool Bay and the adjoining parts of the Irish Sea, a programme of work was adopted and officers were appointed. In addition to several shipowners and leading merchants of Liverpool who supported the enterprise, the Committee consisted of the following scientific men :—

Frank Archer, B.A. (Conchologist), Liverpool.
R. D. Darbishire, F.G.S. (Conchologist), Manchester.
Professor Harvey-Gibson, M.A., Liverpool.
Professor Herdman, D.Sc., Liverpool.
Rev. H. H. Higgins, M.A., Public Museum, Liverpool.
Professor Milnes-Marshall, F.R.S., Manchester.
T. J. Moore, Curator, Public Museum, Liverpool.
Isaac Roberts, F.G.S., Liverpool.
Isaac C. Thompson, F.L.S., Liverpool.
A. O. Walker, F.L.S., Chester.

Amongst others who have joined the Committee during the past 34 years are Dr. W. Evans Hoyle, then at Manchester, Professor Benjamin Moore, then at Liverpool, and Arnold T. Watson, F.L.S., of Sheffield.

The Committee commenced its work by dredging and trawling expeditions in Liverpool Bay from tug-boats and other small steamers, and by examining exhaustively the shore fauna at Hilbre Island and other points in the estuaries of the Mersey and Dee at low tides.

As the result of the first year's work the Committee published an 8vo. volume of 370 pages, illustrated with plates and maps, and entitled "The First Report upon the Fauna of Liverpool Bay and the neighbouring Seas." This volume placed on record nearly 1,000 species, which was increased to nearly 1,850 by the time of the Report to the British Association, published in 1896, and has since reached approximately 2,500.

Hilbre Island is certainly one of the most interesting spots in the immediate neighbourhood of Liverpool, from a biological point of view, and has long been well known to the local naturalists on account of its comparatively rich marine fauna. The rocks at the northern end of the island are covered at and about low water mark by a large and varied assemblage of invertebrate animals, and form a particularly favourable locality for certain Hydroid Zoophytes, Actiniæ, Polyzoa, and Nudibranchs.

The interesting reef-building gregarious Annelid, *Sabellaria alveolata*, is found in abundance round some parts of the shore at Hilbre Island, usually near where sand and rock adjoin. It sticks the sand grains together to form the tubes in which it lives, and so produces masses of a porous, crisp, but brittle material, which crumbles to a certain extent when walked upon, but which is constantly being renewed and has its injuries repaired by the living worms within, and must, therefore, have a very considerable effect in protecting the rocks

from the erosive action to which our sea coasts are exposed.

During the second year's work it became obvious to the Committee that in order to advance further in their explorations and to carry on detailed investigations into the habits and life-histories of the marine animals of the neighbourhood, it would be necessary to establish a small seaside laboratory or biological station at some suitable spot in the district. This idea led, after the consideration of various localities, to the conversion of the old Dock Board observatory and signalling station on the seaward end of Puffin Island, at the northern entrance to the Menai Straits, into a biological station which was opened for work in the summer of 1887 and remained in constant use as the marine laboratory of the Committee until 1892.

The first of our series of 33 Annual Reports gives an account of the natural features of Puffin Island, of the accommodation at the converted observatory, and of the manner in which the Liverpool naturalists and their working party during some days in May, encamped on the Island with their materials and goods; and cleared out, repaired and fitted up the new institution so as to render it habitable. Much work was carried on during the remainder of that summer and autumn by various members of the Committee and other visiting naturalists, and the following sentences may be quoted from the First Annual Report to give some idea of the conditions of work on that lonely island :—

"Shore collecting on Puffin Island on a summer morning, with a low ebb tide, is most delightful work. The naturalist explores the deep crevices and pools in the limestone reefs, lifts up or turns over the smaller of the detached fragments of rock and creeps under the larger ones, peering curiously into all the corners and crannies, and probably oblivious of the pool in which he has placed his knees and of the stream of drops which is trickling down the back of his neck. He sees covering the

lower surface of the stones and festooning the rock delicate sprays of beautifully shaped *Zoophytes*, elaborately sculptured Polyzoa, and masses of incrusting Sponges with gorgeous colouring. He sees strange looking masses of Ascidians, which if incautiously touched suddenly emit two tiny jets of water, thus vindicating their claim to the title of 'sea-squirts.' These and various other marine animals—especially the sea-anemones and the Nudibranchs—almost defy description; they must be seen to be appreciated."

Besides the collecting and identifying of specimens, work on which all the Committee were engaged more or less, various pieces of more detailed research were commenced, and these

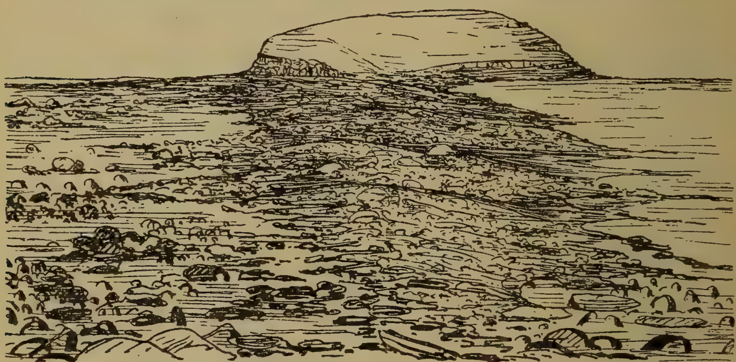


Fig. 1. Puffin Island from the South Spit at low tide.

along with the faunistic results have been reported upon in the various papers and memoirs published in successive years. Mr. Joseph Lomas in this way took up the group of Polyzoa, Dr. Hanitsch started investigations on the Sponges, and Mr. Isaac Thompson from this time onwards till his death in 1903 made notable investigations on the Copepoda, while Mr. Alfred Walker reported on the Higher Crustacea from Amphipoda onwards.

The two functions which the Liverpool Marine Biology Committee endeavoured to fulfil by means of the Puffin Island

Biological Station were, first, to afford opportunity to the younger biologists and students of the neighbourhood of becoming acquainted with marine animals and plants, alive, and in their natural conditions, and of learning how to investigate a fauna and how to conduct marine research in general; and, secondly, to procure supplies of material of the various groups of animals required by the specialists who were engaged in working up the fauna and flora of Liverpool Bay. During the early years most attention was directed towards the second of these functions, and all the earlier reports of the Committee will be found to record additions to the known lists in most groups of animals. Of late years, however, since about 1896, the Committee and their Curator at the later Port Erin Biological Station have paid more attention to promoting the higher education of University students and research which is not purely faunistic.

A prominent feature of the work of the Committee in these early years was the series of dredging expeditions lasting for several days at a time in the "Hyæna" or other steamer lent for the purpose by the Liverpool Salvage Association. In May, 1888, for example, a three days' cruise was undertaken to the Isle of Man, the first day being spent between Liverpool and Ramsey, the second in working along the coast of the Isle of Man between Ramsey and Port Erin, and the third in returning to Liverpool. On this occasion the Committee made some acquaintance with the rich fauna around the south end of the Isle of Man, and this may be regarded as the first step towards the migration from Puffin Island to Port Erin, which was effected four years later. It was on this occasion, while anchored at night in Ramsey Bay, and again the following night in Port Erin Bay, that the Committee successfully used bottom and surface tow-nets containing submarine electric lamps, and captured by this means much larger numbers of certain free-swimming Crustacea than were obtained from

the control nets without illumination. The Crustacea captured in the net with the electric light were mainly Amphipoda, such as *Ampelisca lævigata* and *Dexamine vedlomensis*, and certain Cumacea (*Cuma scorpioides*, *Iphinoë trispinosa* and *Pseudocuma cercaria*), which are rarely met with in quantity. Mr. Walker pointed out in his report that all the Cumacea taken both at Ramsey Bay and Port Erin were males, and that the probable reason is that the males of all the three species represented are provided with pleopoda (or swimmimg legs), while the females are not, and that consequently the males are no doubt more active swimmers, and, therefore, more likely to rise from the sea-bottom where they live. In the illuminated surface nets the remarkable feature was the quantity of Copepoda, which were identified and reported upon by Mr. Isaac Thompson. Apart from the considerable number of species added to our faunistic results by this expedition, the "Hyæna" cruise of May, 1888, is note-worthy on account of the successful application of the electric light as an attraction in both surface and bottom nets worked after dark.

This matter was carried further in a five days' cruise round the Isle of Man at Easter, 1889, when a considerable number of rare and interesting Crustacea (chiefly Schizopoda, Cumacea and Amphipoda) were captured. The large number of Cumacea, and especially adult males of *Iphinoë trispinosa* was a marked feature, not merely in the bottom nets, but also at the surface, in an area which had been illuminated by the electric light for half an hour before the nets were put over. In none of the daylight tow-nettings, either bottom or surface, was a single Cumacean obtained, while every gathering on the two nights when we had the electric light in operation contained Cumacea in abundance. Full details of the matter are given in our third Annual Report. That free-swimming Crustaceans are attracted to a stationary net by the electric light may now, after our experiments of 1888 and on this last cruise, be con-

sidered established beyond doubt; and that the illuminated tow-net can be used in at least moderately deep water was evident to all who saw the success with which the net was worked on board the " Hyæna " in thirty fathoms.

In this year (1889) the second volume of the " Fauna " appeared containing reports on various groups, from Diatoms up to Seals and Cetaceans, including the description of several Invertebrata new to science.

In this year, also, we continued the observations on the " zoning of the shore "—that is, the distribution of characteristic animals and plants in relation to high and low water levels and depths below low water mark—which we had started at Hilbre Island in 1885 and at Puffin Island in 1887, and which leads to some curious results such as that the Polyzoon *Flustrella hispida*, found within a yard of average high water, is exposed to air during about five-sixths of its existence and can only feed and expand during the remaining one-sixth at and about the time of high tide; and that the common rock barnacle, *Balanus balanoides*, is able to live so far above ordinary high water mark as to remain dry for days at a time amounting to eighteen or nineteen-twentieths of its life. Observations were also made on certain other marine animals which can live above high water mark, such as the Copepod *Harpacticus fulvus* and the Gastropod Mollusc *Littorina rudis*.

Other notable features of the work during 1889 were (1) the experiments with Mr. Hoyle's deep-sea closing tow-net designed to capture the plankton in certain limited zones of water intermediate between the bottom and the surface; (2) observations on the structure and function of the highly-coloured processes or cerata projecting from the body of Nudibranchs such as *Dendronotus*, *Tritonia*, *Doto* and *Eolis*, and their usefulness as protecting or warning characters—this matter was continued on future occasions and the results were

fully discussed in a later report*; (3) the faunistic results of various dredging expeditions leading to the addition of some species new to science or to the British seas.

One of the most interesting finds in the following year (1890) was the phosphorescent Schizopod *Nyctiphanes norvegica* obtained in quantity by tow-netting off Puffin Island on an early winter morning before it was light. This organism is found in abundance near the bottom in the deep fjord-like lochs on the west coast of Scotland, and we have since obtained it from deep water in the channel between Ireland and the Isle of Man; and as it has been supposed to be one of those northern forms which have been left behind in a few deep holes as relics of a former fauna (the boreal outliers of Edward Forbes), it is of special interest to find that it comes to the surface at night.

During this year (1890) Professor Harvey-Gibson, along with Mr. George Murray, Mr. E. A. Batters and other visiting botanists, collected and identified the Algæ of Puffin Island and put on record 275 species, including a number of rare forms and at least 27 new to the district (see 4th Annual Report where further details are given).

In this same year Mr. Hornell was working on Polychæt worms, Dr. Hanitsch on Sponges, Mr. Clubb on the Nudibranchiata, Mr. F. G. Pearcey on Foraminifera, and Mr. Thompson continued to add new records of Copepoda to our list, including some unusual forms from tow-nettings taken at night or from nets attached to a buoy and left swinging with the tide for 24 hours. As usual, we had several expeditions in the "Hyæna" or other steamers during the Easter or Whitsuntide holidays, which always added largely to the supply of material for distribution to our specialists.

The following year, 1891, was our last at Puffin Island,

* See Herdman and Clubb, *Quart. Journ. Micr. Sci.*, Vol. XXXIII, p. 541, (1892); also Third Report upon the Nudibranchiata, in 'Fauna,' Vol. III.

as the Committee had now decided to establish a more important laboratory at Port Erin near the south end of the Isle of Man in order that they might have the opportunity of investigating the rich marine fauna of that neighbourhood. The Fifth Annual Report contains many records of additions to most of the groups of marine Invertebrata, and some observations on the distribution and habits of shore animals. The following paragraphs may be quoted as an example of some of our experiences during the days that many of the Committee spent from time to time on Puffin Island :—

"During the remainder of our stay the weather was perfect. In fact, on the second day it was so calm that in the evening at low tide we were able to row into the wonderful 'sponge caves' on the north side (which can only be entered at the lowest of tides and on a calm day, and then only in a small boat), for the purpose of inspecting their treasures. The two large caves are close together, and have been hollowed by the sea out of the bases of the high limestone cliffs. Their mouths face seawards towards the Irish coast, and on entering the boat has to be pushed (it is too narrow to row) through a long tunnel-like passage, with vertical walls, to the inner end, with its small piece of sloping gravel beach, where one can land—in the dark. On striking a match it is seen that the sides of the cave are closely encrusted with various kinds of colonial and sessile animals, especially with sponges, the characteristic feature of the place. Here one revels in *Pachymatisma johnstoni*, *Dercitus bucklandi*, *Plumohalichondria atrosanguinea*, and other many-hued slimy-looking Tetractinellids and Monactinellids. Here we first found, a few years ago, the rare new genus which has been named 'Sciriola,' in honour of our sainted predecessor on the isle (probably a good biologist according to the lights of his day and generation), who lived, as the naturalist always loves to do, beside the sea, the rocks, and the Puffins, and who possibly shoved his coracle on a calm

evening into the sponge caves and saw in the dim light those curious white masses on the rock which some thirteen centuries after were dedicated to his memory. . . . .

"We collected altogether on this occasion thirteen species of Nudibranchs, including the rare *Eolis landsburgi;* also a very remarkable sponge belonging to the genus *Suberites*, and another sponge of a dark orange colour—one of the Desmacidonidæ—which was found by Dr. Hanitsch in one of the caves. This will probably turn out to be an interesting novelty as the sponge is in symbiosis with a Zoophyte. The hydrorhiza of the Zoophyte permeates the sponge in all directions and replaces to a certain extent the missing spongin fibres. The spicules of the sponge are found echinating the hydrorhiza of the Zoophyte."

This brings us to the time of the formation of the Lancashire Sea-Fisheries Committee, with which, from the first, we established friendly, and immediately afterwards, official connections. Mr. R. A. Dawson, the Fisheries Superintendent of the district, took part in some of our expeditions and gradually enlisted our services in Sea-Fisheries work, which led to considerable results in the future.

The Sixth Annual Report, for the year 1892, started a new record as the first of the series of nearly thirty reports dealing with the Biological Station at Port Erin. The Puffin Island establishment had been very useful to the Committee, and was well worth the small annual expenditure required for its modest outfit. It had been used by some students of the local Colleges who wished to gain a general knowledge of the common marine animals and plants in a living state, and by a considerable number of specialists who went there to make observations, or who had the material for their investigations collected there and sent to them.

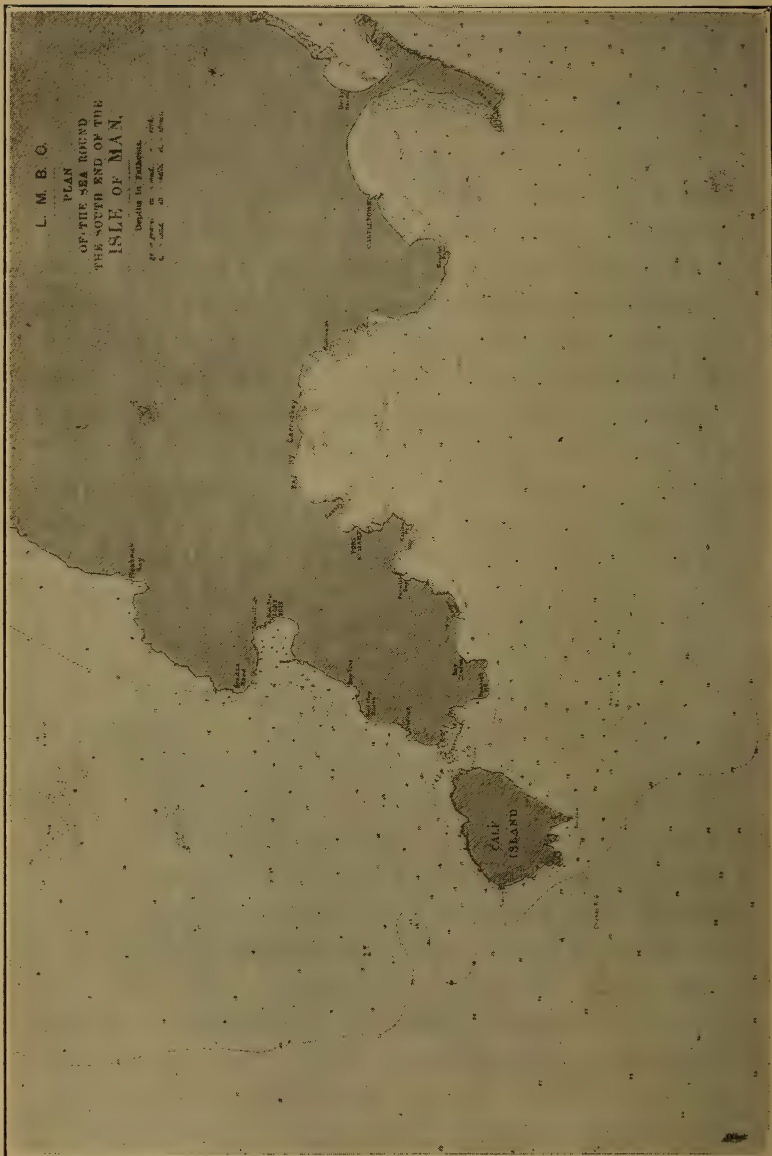
It had been felt, however, by the Committee for some time that a station which was more readily accessible from

Liverpool, and with hotel or lodging accommodation on the spot, would enable their specialists to do more work, and be of more use to students and investigators generally. Also it was becoming evident that after five years work on the shores of the small island the greater number of the plants and animals had been collected and examined, and that a change to a new locality with a rich fauna and a more extended and varied line of coast would yield increased material for faunistic work.

After considering many possible localities on the shores of the Irish Sea, the Committee unanimously decided that no other spot seemed to be so suitable and to offer such advantages for their work as Port Erin at the south end of the Isle of Man. As a result of several visits and negotiations with local authorities, a simple building*, containing a couple of small laboratories and some aquarium tanks only, was erected on the shore close to high-water mark on the north side of the Bay, and a formal opening by the Lieutenant-Governor of the Island (Sir Spencer Walpole), in the presence of a large number of marine biologists and others interested, took place on June 4th, 1892. A full account of the inauguration will be found in the Report for that year. And so we moved from Puffin Island, Anglesey, to Port Erin, Isle of Man—as was said at the time, from "the Mona of Tacitus to the Mona of Caesar"—a step that has proved advantageous in every respect.

The Port Erin Station occupies a fairly central position in the Irish Sea, being about 30 miles from Ireland, 33 miles from Scotland, 40 miles from Wales and about 45 miles from the nearest point of England. The Bay faces nearly West and is in most winds a good natural harbour with sand at the inner end and bounded by precipitous cliffs beyond to the North and South. From its position and the shape of the land Port Erin has, within a distance of a couple of miles in three directions,

* Replaced in 1902 by the present much larger institution on the opposite side of the Bay.


L. M. B. C.
PLAN
OF THE SEA ROUND
THE SOUTH END OF THE
ISLE OF MAN.
Depths in Fathoms.
CASTLETOWN
Bay Ny Carrickey
PORT ST MARY
CALF ISLAND

to Fleshwick Bay, to the Calf Sound and to Port St. Mary, a long and varied coast-line with a number of small bays furnishing good collecting grounds and shallow water dredging. Two of these bays, Port Erin and Port St. Mary, have harbours with sailing-boats and face in nearly opposite directions, so that in most winds one or other is sheltered and has a quiet

FIG. 3. Plan of the L.M.B.C. District, with section across the Irish Sea, through Douglas.

sea for inshore work. The rich fauna around the Calf Island and off Spanish Head is within easy reach, while at a distance of three to four miles from the Biological Station are depths of 20 to 30 fathoms and at 14 miles, 60 to 80 fathoms (figs. 2 and 3).

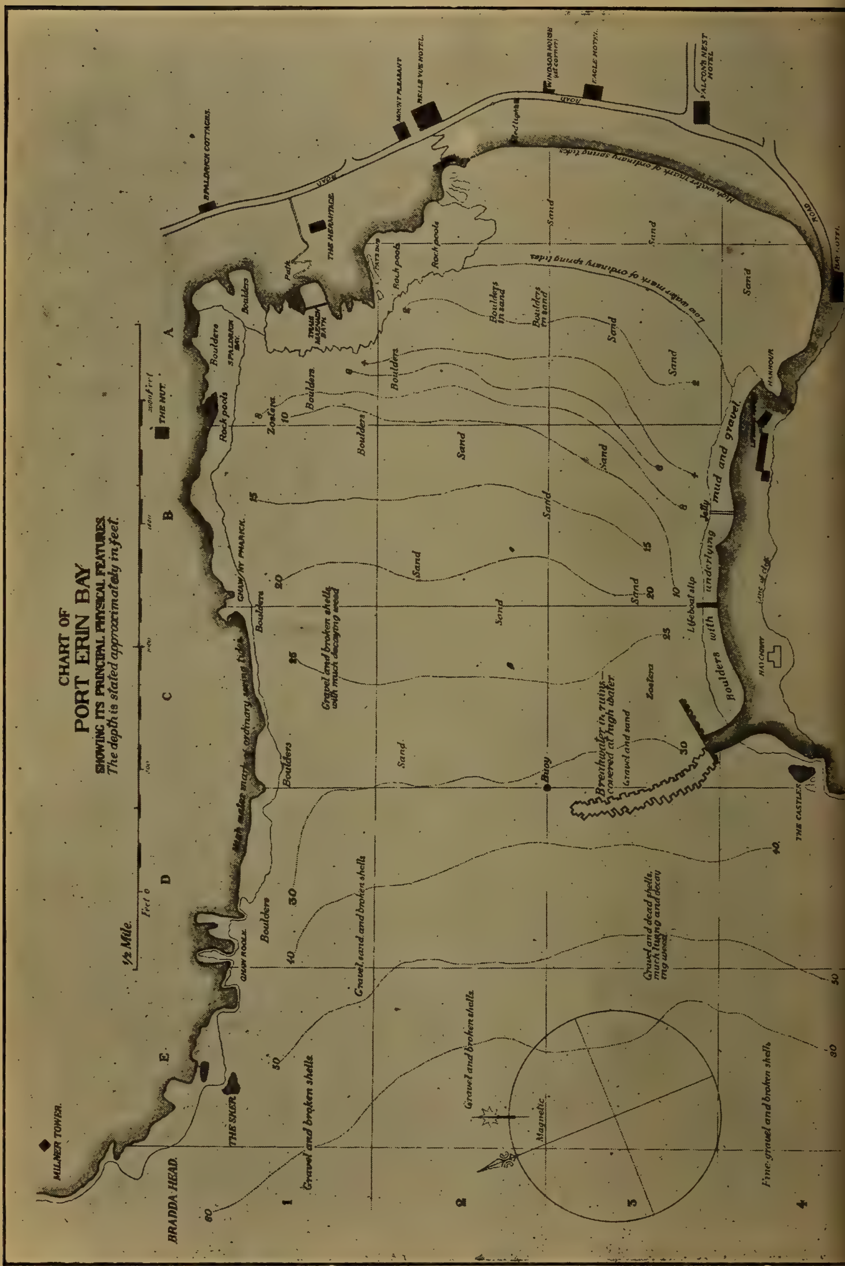


CHART OF
PORT ERIN BAY
SHOWING ITS PRINCIPAL PHYSICAL FEATURES.
The depth is stated approximately in feet.
½ Mile.
BRADDA HEAD.
MILNER TOWER.
THE SKER.
SPALDRICK BAY.
SPALDRICK COTTAGES.
THE HERMITAGE.
THE HUT.
Rock pools
Boulders
Sand
Zostera
Gravel and broken shells
Gravel and broken shells with much decaying weed
Gravel, sand and broken shells
Gravel and dead shells, much living and decaying weed
Fine gravel and broken shells
Breakwater in ruins, covered at high water
Gravel and sand
Buoy
Lifeboat slip
Boulders with underlying mud and gravel
Jetty
HARBOUR
HAYCROFT
THE CASTLES
Low water mark of ordinary spring tides
High water mark of ordinary spring tides
Magnetic
MOUNT PLEASANT
BELLE VUE HOTEL
WINDSOR HOUSE
EAGLE HOTEL
FALCON'S NEST HOTEL
ROAD
Path
A
B
C
D
E
1
2
3
4

FIG. 4.

The plan of Port Erin Bay (Fig. 4) shows the position and surroundings of both this first and also of the present larger Biological Station, and gives some idea of the depths and nature of the collecting grounds inside the Bay.

On the occasion of the opening of the Station the Liverpool Salvage Association lent their steamer "Mallard" for several days dredging and tow-netting around the south end of the Island, when large collections were made at depths down to 60 fathoms.

The opening of the Biological Station at Port Erin at once led to greatly increased numbers of workers, and during the summer of 1892, in addition to members of the Committee and Liverpool students, marine biologists from Manchester, Sheffield, Cambridge, Aberystwyth, London and Edinburgh spent some time in the laboratory. Mr. W. J. Beaumont from Cambridge made some interesting observations on the polypes of the rare Alcyonarian *Sarcodictyon*, and Mr. E. T. Browne from London started those investigations on the Medusoids of Hydroid Zoophytes upon which he has written many papers since.

Amongst other interesting animals found during that summer in the immediate neighbourhood of Port Erin were the Foraminifera, *Astrorhiza limicola* and *Haliphysema tumanowiczii*, the tubicolous Infusorian *Folliculina ampulla*, the Turbellarian *Convoluta*, the remarkable worms *Dinophilus tæniatus* and *Spadella*, and quite a number of Nudibranchs and Compound Ascidians. Mr. Walker continued to add new records of Amphipoda and Mr. Thompson of Copepoda, one of the latter being *Notopterophorus papilio*, an interesting addition to our fauna.

At the meeting of the British Association held that summer in Edinburgh some of our more active workers were constituted a Research Committee of the Association with a grant to be expended in exploring further the southern part of the Irish

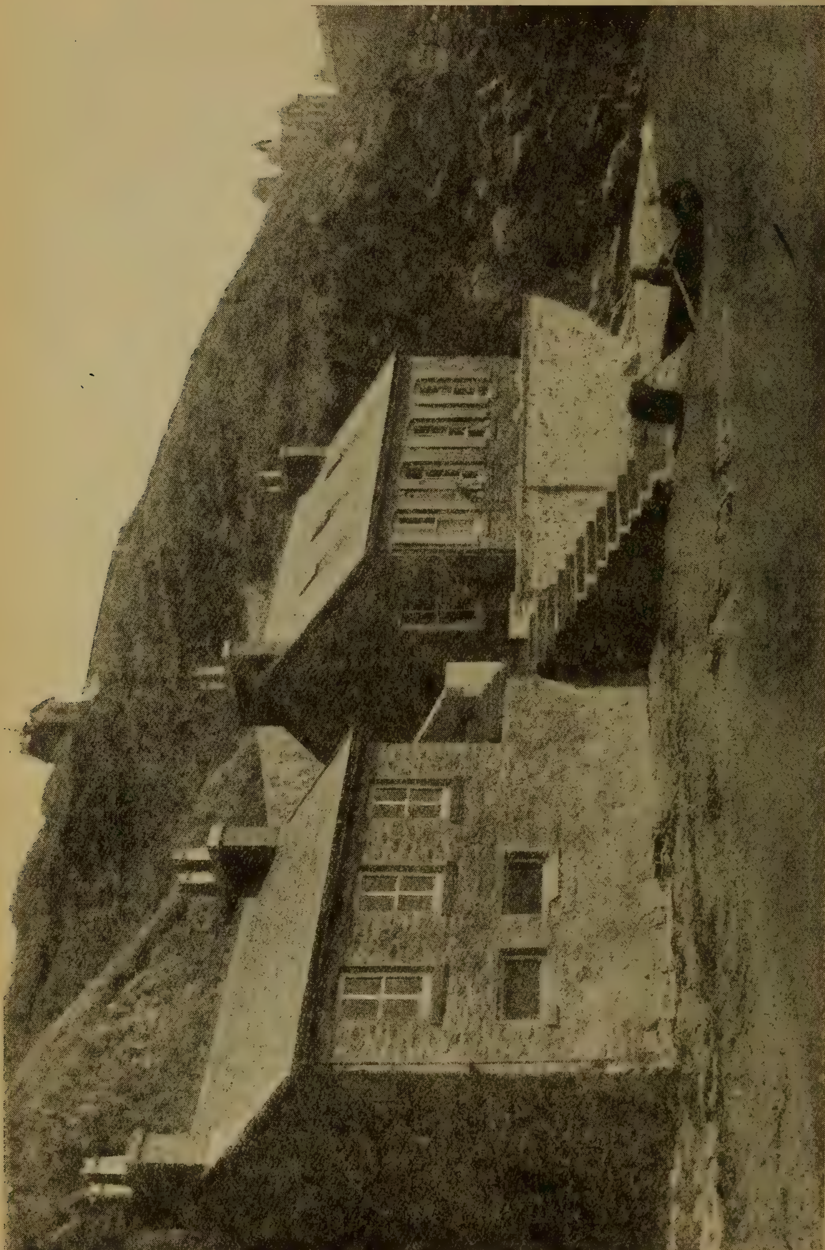


Fig. 5. The original Biological Station at Port Erin.

Sea. This British Association Committee continued its work for four years, furnished reports to successive meetings of the Association and in its final report, to be found in the volume for 1896, gave a complete list of all species recorded up to that date as the result of our explorations.

The third volume of the Fauna was published in July, 1892, and contained papers on the Marine Algæ, Sponges, Worms, Crustaceans, Mollusca and Ascidians.

Finally, in this Sixth Report (1892) a record is given of some observations on the remarkable variations in colour of the small shore prawn *Virbius* (or *Hippolyte*) *varians*, illustrated by a coloured plate showing a brown *Virbius* simulating the elongated segmented brown floats of the brown sea-weed *Halidrys siliquosa*, a red and white banded *Virbius* found inhabiting masses of the red sea-weeds *Delesseria* and *Rhodymenia*, and a bright green *Virbius* lying lengthways along the blades of the green sea-grass *Zostera marina*, and bearing eggs which are also green, while specimens found on a sandy bottom or on small gravel are mottled black, grey and white, so as to be very effectively protected by their colouration. This matter was investigated in much more detail some years later by Professor Gamble.

In the following Report, for 1893, we find a list of over 60 workers who made use of the Station for collecting or investigation, including Professor Brady and Professor Potter from Newcastle, Captain Dannevig from Norway, Professor G. B. Howes from London, and others.

Captain Dannevig's visit was at the request of the Lancashire Sea-Fisheries Committee, in order that he might give evidence before them as to the suitability of the locality for a Fish-Hatching establishment. He reported both to that Committee and also to the Select Committee of the House of Commons on June 15th that he regarded Port Erin as the most suitable place in the neighbourhood for the establishment

of such an institution for fish culture. It may be added here that legal and administrative difficulties were found to be an insuperable bar, and the Lancashire Committee had to find another locality, namely, Piel Island in the Barrow Channel, within their own administrative district; but some years later the Manx Government took up the same matter, and in co-operation with the Liverpool Marine Biology Committee erected the new Biological Station and Fish Hatchery at the opposite side of Port Erin Bay. A connection was, however, at this time established between our Port Erin Station and the Lancashire Sea-Fisheries Committee, which has been continued through the intervening years, has led to a good deal of co-operation, and will be still closer in the future now that the scientific work of both is united in the Department of Oceanography at the University of Liverpool.

On several occasions in 1893 we had the use of the Lancashire Sea-Fisheries steamer "John Fell" for taking observations in the deeper waters around the Isle of Man, and especially in the deep channel lying between Port Erin and Ireland, where we worked down to a depth of 79 fathoms in the interesting assemblage of mud-inhabiting animals, including *Bougainvillia muscus*, *Adamsia palliata*, *Sagartia herdmani* (on *Turritella* shells), *Porania pulvillus*, *Palmipes membranaceus*, *Amphiura chiajii*, *Brissopsis lyrifera*, *Lumbriconereis* sp., *Panthalis oerstedi*, *Lipobranchius jeffreysii*, *Hyalinœcia tubicola*, *Alcyonidium gelatinosum*, *Scalpellum vulgare* (on *Antennularia*), *Calocaris macandreæ* with its associated Polyzoon *Triticella boeckii*, *Rissoa abyssicola*, *Nucula sulcata* and *Isocardia cor.*

A further account of work on this ground and of the nature of the bottom deposits in various parts of our area will be found in the report for the following year, which includes also a record of Mr. Arnold Watson's interesting observations on the method of tube-building by *Panthalis oerstedi*. From this time onwards Mr. Watson took up this subject, the method

of building sandy and muddy tubes by various common Polychæt worms as his specialty, and made a number of interesting observations which were communicated in successive years to meetings of the British Association, and were from time to time recorded in our Reports. He was wonderfully successful in keeping dredged Annelids alive for long periods so as to be able to study their habits. Even the deep-water *Panthalis*, dredged from 70 fathoms, was induced by him to live in a few inches of water in a small aquarium at the Biological Station, where it deserted its old tube and proceeded to form a new one in the mud against the glass side of the aquarium so as to expose all its operations to Mr. Watson's careful observation.

A considerable number of other additions to the fauna, chiefly of microscopic forms such as the Copepoda, will be found in each of these Annual Reports about this period when dredging expeditions were so frequent.

Our British Association Committee, which continued its work, was now requested by Sir Archibald Geikie (then Director-General of the Geological Survey) to form a series of samples of the various deposits brought up by the dredge from various parts of the Irish Sea for examination and preservation in the Museum of the Geological Survey at Jermyn Street. For several years after this, samples of the deposits were packed in small canvas bags and sent to the Museum. These have been reported on by Professor Watts, the late Mr. Clement Reid and others (see especially the Seventh Annual Report, pp. 30-32, and the Eighth Report, p. 35).

Amongst other observations of bionomic interest which were made at this time I may mention the swarms of the common shore Amphipod *Orchestia gammarellus* which on several occasions migrated upwards from the shore far above high-water mark, invaded the Biological Station in countless numbers so as to cover the floor, tables, shelves, window-

ledges and even dishes placed high on the walls, in great profusion. They were seen to be jumping up the steps leading from the beach and to be able to climb the vertical concrete wall of the Station to a height of several feet. These invasions seem to be on occasions of exceptionally high tides coinciding with a heavy shower of rain.

In the Report for the following year, 1894, we see the beginnings of the connection which was afterwards established between the Liverpool Committee and the Isle of Man Government for the promotion of fish culture at Port Erin. An Act of Tynwald was passed creating a Fishery Board for the Island with powers to make bye-laws and promote the local fishing industries in other ways. This movement led to the introduction of fisheries work at the Biological Station. Observations on the spawning seasons and localities and experiments in the hatching of the fertilised ova of various food-fishes were carried on during this and following years.

It may be of interest to insert here the following account of the procedure adopted on one of the dredging expeditions in this year. It is a good example of the advantages of "team-work" in such an investigation.

"When the first locality is reached the spot is determined on the chart, and the depth verified by a cast of the lead. Then the dredge (measuring 2 feet 6 inches by 1 foot, and weighing from 30 to 40 lbs.) is sent down with a tow-net tied on the rope about two fathoms from the dredge. Very often a smaller dredge with a bag of cheese-cloth is sent over on the other side of the ship. One or more surface tow-nets are also put out. The tow-nets, both surface and deep, are looked after by Mr. I. C. Thompson, who first turns out their contents into a clear glass jar of sea-water, and then, after noting the general character of the catch and any specially conspicuous forms, strains off the water through a small bag made of very fine millers' silk, and transfers the 'plankton' left adhering to the

silk to a tube containing his special preservative fluid formed of spirit, glycerine and water in certain proportions.

"When the dredge is brought up it is emptied on deck, and after a note of the general character of the deposit and assemblage of animals has been taken, any specially large or rare specimens are picked out and transferred to buckets or jars of sea-water, or to store-bottles of spirit. Then the heap is spread out so as to form a layer not more than one or two inches in depth, and one or two members of the Committee (Herdman and another, Walker or Leicester) now settle down beside it to pass the entire mass in review inch by inch, working it across a small space of bare deck and turning over every shell, stone and specimen with an iron spoon, so as to ensure that nothing escapes observation and due record in the note-book. In the meantime the contents of the bottom tow-net have been dealt with by Mr. Thompson, and the apparatus has been lowered for a second haul, or the vessel is steaming on to a new locality. Then a fair sample of the deposit is selected for preservation (for the Geological Survey) in a small canvas bag (10 by 5 inches), care being taken to include some of the characteristic bottom animals—shells, ophiuroids, polyzoa, etc.

After this sample has been removed, and special animals required have been picked out and put into store-bottles, the whole of the remainder of the haul is passed gradually through our set of three sieves (meshes $\frac{3}{4}$ inch, $\frac{1}{4}$ inch, and $\frac{1}{8}$ inch respectively), which work up and down in a tall iron cylinder filled with sea-water. The sieves are disconnected and examined at intervals, and in this way many of the smaller animals of all groups are detected and picked out. Finally, the water in which the sieves have been plunging is strained by Mr. Thompson through his fine silk net, and in this way many of the rarer bottom Copepoda are obtained, while the finer sandy and muddy deposits retained by the finest sieve or in the bottom of the cylinder are packed in canvas bags by Mr.

Alfred Leicester for further examination at home. These contain, of course, many minute Mollusca, Ostracoda and Foraminifera. By the time these various processes have been completed the dredge has usually been hauled again, and a fresh heap is lying on the deck awaiting investigation. On a successful trip the members of the party, on an average four to six in number, are kept constantly occupied, each man at his own work, from the commencement of the first haul till the steamer is turned homewards, and after that the packing and labelling of specimens fill up the time until land is reached."

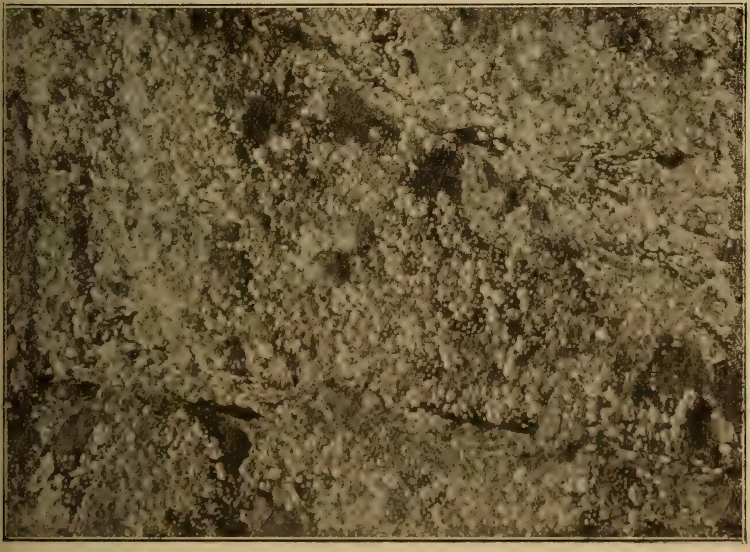
This year Professor G. S. Brady reported on our gatherings of Ostracoda and furnished us with a considerable list which is printed in the Report, including several rare forms and one new to Britain.

The work of the Rev. T. S. Lea in photographing characteristic specimens of the marine algæ *in situ* at low-tide commenced about this date and was continued for some years. Mr. Lea also photographed the rocks and stones of some of our best collecting-grounds and some of the assemblages of animals brought up on our dredging expeditions (Figs. 6, 7 and 8 show some examples of Mr. Lea's work).

In this year also we started the investigation of the movements of swarms of Copepoda, Medusae and other more abundant members of the plankton, and endeavoured to ascertain the result of the prevalent currents, tidal or otherwise, by distributing large numbers of "drift-bottles" containing numbered notices to be filled in with locality and date and be returned by the finder. This method of setting free drift-bottles and keeping records of their travels was continued for some years, and has also been practised by the Fishery Board for Scotland, the U.S. Coast Survey, the Prince of Monaco and others.

Volume IV of the Fauna was issued early in 1895, and this brings the reports on the work of the Committee up to the

June, 1897.



June, 1898.

Fig. 6. Vertical rock-face, Port Erin, six feet above low-water.
[*From photographs by Rev. T. S. Lea*]

end of the tenth year. In this year we find also the commencement of the investigations by Professors Boyce and Herdman on the life conditions and health of the Oyster and the incidence and effect of certain diseased conditions. The results were communicated to successive meetings of the British Association, and were also published in the Annual Reports of our Committee. The experimental work was carried on during these years partly at Port Erin and partly in the laboratories of Liverpool University.

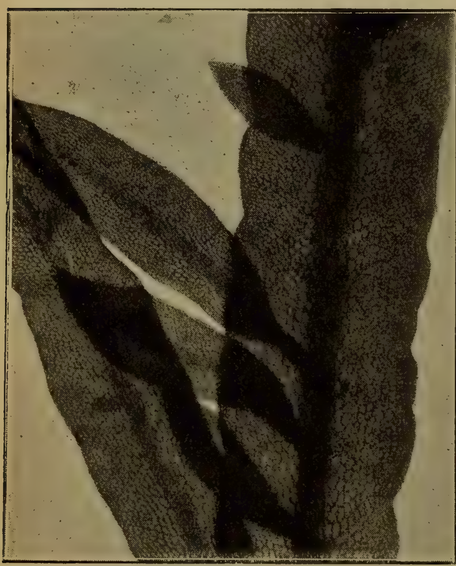


FIG. 7. *Delesseria hypoglossum*, magnified.

FIG. 8. *Himanthalia lorea*, showing th button-like fronds and th thong-like fructification.

It is unnecessary to record year by year the dredging and collecting expeditions and the various additions made to the fauna. Lists of them will be found in the successive Reports. But it may be mentioned that about this time Mr. Andrew

Scott, Assistant Naturalist on the staff of the Lancashire Sea-Fisheries, became very active in investigating the Copepoda along with Mr. Thompson, and added many rare and some new species to our lists. Some examples of the assemblages of animals found in characteristic hauls in different parts of the Irish Sea will be found in this year's Report (1895). The first given, for example, records at least 112 species belonging to 103 genera, represented by probably about 300 specimens; and many other hauls taken on the prolific ground to the west of the Isle of Man gave us on an average about 100 species. On the other hand hauls taken off the Lancashire coast in shallow water gave fewer species but far more individuals, one, for example, bringing up over 17,000 specimens belonging to 39 species.* We have other unpublished records of hauls in Liverpool Bay where the total reached such enormous numbers as from 45,000 to 50,000 specimens, not including microscopic forms. In connection with these hauls a good deal of attention was paid during this and succeeding years to the nature of the bottom and to the classification of the deposits and of the amounts of silica and calcium carbonate found in typical terrigenous and neritic deposits in the various parts of the Irish Sea.

One of the events of the following year (1896) was the visit made to the Port Erin Station by a large party (about a hundred) of biologists, including geologists and anthropologists, who had attended the meeting of the British Association in Liverpool that summer. The visitors from other countries included Professor Gilson from Louvain, Dr. Hjort from Christiania, Dr. J. G. De Man from Holland, Dr. Gilchrist from Cape Town, Professor Chodat from Geneva, Dr. Montelius from Stockholm and others.

* *See* Lancashire Sea Fisheries Memoir, No. II, "Fishes and Fisheries of the Irish Sea," by Herdman and Dawson, 1902.

The sea-anemones of the neighbourhood, which live exceedingly well for long periods in our aquarium tanks, began to receive attention, and a first list of 21 species was published in this Tenth Report. We have since added at least eleven additional records to the Zoantharia.

The following year (1897) showed steady progress in several directions. Our fish hatching experiments were now conducted on a larger scale and dealt with the eggs of Lemon Soles, Witches and the Megrim; and suggestions and plans began to be made in regard to the Fish Hatchery which were eventually carried out in connection with the new Biological Station a few years later.

The investigations in connection with the bacteriology of the Oyster, and Mr. Lea's photographic records of organisms in their characteristic haunts on the littoral zone were also continued. Professor Ashworth started his investigation of the species of *Arenicola* which led eventually to his writing one of the L.M.B.C. Memoirs on that type. Dr. Lyster Jameson worked on Turbellaria and eventually contributed a paper on the subject to our Reports.

One of the remarkable animals dredged this year was the new green Gephyrean worm which was described in the Quarterly Journal of Microscopical Science as *Thalassema lankesteri*. It is related to *Hamingia*, *Echiurus* and *Bonellia*, and is coloured by a remarkable green pigment (thalassemin) which differs in detail from other green tegumentary pigments of allied worms.

Late in the year 1897 the Committee appointed, as Resident Curator of the Biological Station, Mr. H. C. Chadwick, A.L.S., who commenced his duties at the beginning of 1898 and has continued to occupy the post from that date to the present day. Each Annual Report from the time of Mr. Chadwick's appointment contains a report from the Curator, dealing with the numbers of students and visitors to the Station

and the progress of work in the Aquarium. Mr. Chadwick also started the practice of taking meteorological observations, including the temperatures of sea and air, twice daily. These records, continued now over a period of twenty-two years, ought to be of great interest and probably some scientific value in relation to variations of the marine fauna.

The large red buoy that marks the end of the breakwater at the mouth of Port Erin Bay, and which is moored in a depth of about five fathoms, was carefully scraped in the summer of 1898 when brought ashore for its annual cleaning, and that process has been repeated on many occasions since with excellent zoological results. On that first occasion it may be noted that the assemblage of animals, amounting to over 30 species, was as follows :—*Sycon compressum*, *Bougainvillia ramosa*, *Coryne* sp., *Tubularia larynx*, *Eudendrium ramosum*, *Obelia geniculata*, *Clytia johnstoni*, *Sertularella rugosa*, *Nereis* sp., *Terebella* sp., *Sabella* sp., a Nemertine, *Bicellaria ciliata*, *Scrupocellaria* sp., *Membranipora membranacea*, several Amphipods and Isopods, *Nymphon gracile*, *Doto fragilis*, *Ciona intestinalis* (very abundant), *Ascidia mentula*, *Styela grossularia* (abundant), *Corella parallelogramma*, and at least half-a-dozen undetermined species ; while during the recent summer (1919) the species obtained on a similar occasion when we scraped the yacht moorings, close to the buoy, were as follows :—*Leucosolenia* sp., *Sycandra ciliata*, *Sagartia* sp., *Obelia geniculata*, *Eucratea chelata*, *Membranipora membranacea*, *Lepralia* sp. *Canda reptans*, *Polynoe* sp., *Nereis* sp., *Sabella pavonia*, *Spirorbi* sp., *Virbius varians*, *Hippolyte* sp., *Mysis* sp., *Galathea* sp., *Idothea baltica*, *Caprella linearis*, *Jassa falcata*, *Dexamine spinosa*, *Gammarus locusta*, *Hyas araneus*, *Phoxichilidium femoratum*, *Pecten opercularis* (young), *Anomia ephippium*, *Saxicava rugosa*, *Eolis drummondi*, *E. farrani*, *Doto fragilis*, *Hydrobia ulvæ*, *Helcion pellucidum*, *Ciona intestinalis*, *Ascidia*

aspersa, *Botryllus smaragdus* and *B. schlosseri*—about the same total number, but rather a different assemblage of species.

It may be of interest to know that in that first year of Mr. Chadwick's curatorship the number of visitors who paid for admission to the Aquarium was 500, while in the past summer (1919) the number was over 23,000.

The work on the green colouration of certain oysters, and on the connection between oysters and certain bacterial diseases, which had been started a couple of years previously by Professors Boyce and Herdman, with the help of Dr. Charles Kohn, was continued and brought to an end during this and the following year when the detailed evidence and results were published by the Lancashire Sea-Fisheries Committee in the form of a Memoir entitled "Oysters and Disease." A summary of the results is given in our 12th Annual Report, showing that there are several distinct kinds of greenness in oysters, some of which are quite healthy, and are due to the natural vegetable food of the animal, as in the case of the green Marennes oysters in France and those of some rivers on the Essex coast; while others are diseased conditions due to the storing up of an abnormal amount of copper in the blood or other tissues. For the bacterial results we must refer those interested to the details given in the Memoir. But it may be added that our work showed the necessity for the periodic examination by scientific inspectors of all oyster beds and other grounds from which mussels, cockles or periwinkles are gathered for human food.

The Report which appeared during this year of the Manx Industries Commission recommended that a Fish Hatchery should be established in connection with the Biological Station at Port Erin. Another new departure, which was proposed in the 12th Annual Report, was the issue of a series of L.M.B.C. "Memoirs," each giving a full account, by one of our specialists,

of some common and typical animal, for the use of students in University laboratories and biological stations. This series was commenced with a Memoir on "Ascidia," published in October, 1899, and has been continued for the last twenty years, twenty-three of such Memoirs having now appeared.

The following year, 1899, is noteworthy as the date of the Stockholm Conference for the purpose of initiating an International Exploration of the North Sea and neighbouring waters, in the interests of the Fishing industries. The project was advanced a stage further by the succeeding Conference at Copenhagen in 1900, and subsequently became an established convention between nine or ten of the Governments of North-west Europe, and has resulted in the publication of a very large quantity of work of a biological and oceanographic nature. In the arrangements put forward at both these original Conferences, and also in further declarations issued since, the programme of work omits any reference to the Irish Sea and the greater part of the West Coast of Scotland, which left us at any rate a free hand to continue the investigation of our own district in our own manner.* As a critic in "Nature" (November 16th, 1899) said at the time :—" With an elaborate organisation, such as that suggested by the Conference, there is a danger that the work of the biological stations would degenerate into the mere taking and recording of routine observations, whilst original work and the development of new methods of research, which are in reality of far greater importance, would receive a check. Good men would certainly not be attracted to work which consisted merely in recording observations taken according to a stereotyped plan dictated

* This independent investigation of the Irish Sea was subsequently arranged and carried out in collaboration with the Lancashire and Western Sea Fisheries Committee and the Irish Fisheries Department, and periodic hydrographical cruises were made by the Lancashire Sea fisheries steamer for several years up to September, 1914. It is hoped that this work at sea will soon be resumed.

by a central bureau. A large amount of individual freedom to the workers is absolutely essential in order to secure the best results from scientific research."

A good deal of detailed plankton work was done during this year by Mr. Chadwick and others, and we published in the 13th Report some excellent figures of larval forms of Planarians and "Tornaria," along with Holothurian, Star-fish, and other Echinoderm larvæ, which eventually led to Mr. Chadwick's L.M.B.C. Memoir on "Echinoderm larvæ."

By the following year, 1900, the first four L.M.B.C. Memoirs, dealing with "Ascidia," "Cardium," "Echinus" and "Codium," had been published, and also the fifth and last volume of the Fauna, containing reports on new Copepoda by Isaac Thompson, on Hydromedusæ by E. T. Browne, on Turbellaria by H. Lyster Jameson, and some other marine studies. At the end of the volume will be found a complete list of all the species of marine plants and animals recorded up to that date from the Irish Sea area. This list, as it gives references to the various Annual Reports or volumes of the Fauna in which the record was first made, constitutes a useful index to our faunistic publications up to this date. A list of the additions made since will be found at the end of this Report. Amongst interesting additions made to the fauna during 1900 may be noted the Nudibranchs *Doris diaphana* and *Hero formosa*, the Siphonophore *Cupulita sarsi*, the Actinians *Arachnactis albida* and *A. bournei*, and quite a number of new Copepoda recorded by Andrew Scott and Isaac Thompson. In this year's Annual Report we published the first of our series of distributional charts, Plates I. to VII., showing the physical configuration of Port Erin Bay and the neighbouring parts of the coast, and the distribution of the characteristic species of the leading groups of animals, as the result of our dredging expeditions during the preceding eight years.

The 15th Annual Report (1901) begins as follows:—

"The most important event that falls to be recorded this year is the arrangement concluded with the Government of the Isle of Man, as a result of which we shall in future occupy increased laboratory accommodation, and be responsible conjointly with a committee of the Tynwald Court for the conduct of a large Aquarium and Fish Hatchery. A detailed statement as to how this change has been brought about, as to the position of our Committee in relation to the Manx Government, and as to the probable effect upon our work will be given below. But it must be obvious to all that as this implies a removal from our present Biological Station to larger and more convenient buildings, on a better site at the other side of the bay, it is clearly the most important event in the history of the L.M.B.C. since we first established our laboratory at Port Erin."

Mr. Chadwick in this report added several species to our record, Mr. Andrew Scott gave a useful list of new fish-parasites and Crustacea, and Mr. A. D. Imms studied several kinds of shore insects in preparation for his L.M.B.C. Memoir on "Anurida" (published in 1906). The only other event of this year that need be recalled is that we prepared and published as an Appendix to the Report, and also separately, an illustrated Guide to the Aquarium, "being a short account of some of the common marine animals of the neighbourhood." This Guide, and the revised and enlarged editions which followed it, has met with much success, and many thousands of copies have been sold at 3d. each to visitors. The last 1,666 copies of the third edition have been sold during the present summer, and a new edition is now in preparation.

The 16th Report is the first of a new series recording the work done at the much larger permanent Biological Station on the south shore of Port Erin Bay. This building, combining Laboratory, Aquarium and Fish Hatchery, was erected by the Manx Government in pursuance of a report of the Industries

Commission and of an agreement between a Committee of Tynwald Court and the L.M.B.C.; and it was opened for work in the summer of 1902. The Report for that year contains a full description of the building and equipment and of the arrangement by which the Tynwald Committee and the L.M.B.C. share the expense and the control of the joint institution. The arrangement has worked smoothly and well for the last eighteen years and will no doubt continue to do so in the future under the new agreement by which the Oceanography Department of the University of Liverpool assumes the place and responsibilities of the Liverpool Marine Biology Committee.

This Report contains a first account of the local fishing industries of Port Erin drawn up by the Assistant Curator, Mr. T. N. Cregeen. As usual, additions to the recorded Fauna, made by Andrew Scott, A. D. Imms, E. T. Browne and others, will be found in the Report.

Our eighteenth year of work (1903) closed under the shadow of a recent sorrow and in presence of a serious loss. "Mr. Isaac C. Thompson has been the Honorary Treasurer and business-head of the Committee since its foundation in 1885, and his sudden death in November has left a gap in our life and work which no one man can fill. We shall be fortunate if we obtain in his successor the devoted Treasurer without requiring him to be also the accomplished Naturalist." A brief memoir of Mr. Isaac Thompson's life and work was appended to the Report. His son, Mr. Edwin Thompson, was fortunately able to take up and complete his father's work for that year, and eventually he was appointed Honorary Treasurer to the Committee and has acted in that capacity to our great satisfaction for the last sixteen years.

The 17th Report (1903) contains the first record of the remarkable swarm of the large Copepod *Calanus finmarchicus* which appears in Port Erin Bay nearly every year in July. There are also variuos additions to the fauna and other records

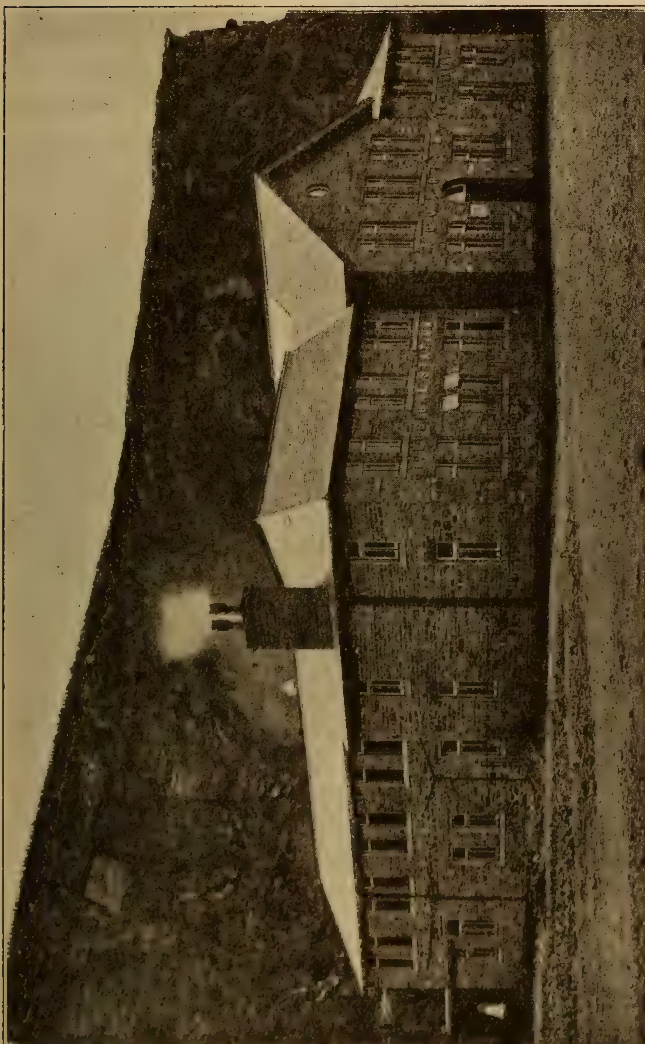


FIG. 9. The new Biological Station at Port Erin. [*Photo. by Prof. F. J. Cole.*]

of a routine nature, and it may be noted that during this and the preceding two years the Committee issued L.M.B.C. Memoirs on "Alcyonium," "Lepeophtheirus" and "Lernæa," "Lineus," "Pleuronectes," "Chondrus," and "Patella."

Each successive year now began to show an increase in the number of investigators doing original work at the new Laboratory, and an increased interest in the public as shown

Fig. 10. Students at a field-demonstration.
[*Photo. by Prof. W. J. Dakin.*

by the numbers of visitors to the Aquarium. Each year also showed important additions to the accommodation and equipment at the Station, such as the addition of a second storage tank on the cliff behind, improvements in the Fish hatching and in the circulation of water in the Aquarium tanks and in the facilities for students' work. "Many of our Univer-

sity students have supplemented their biological work in the Laboratory with occasional days devoted to Geology and Archæology on the hills. On some of these occasions we have had the advantage of being accompanied by Mr. Lomas as our leader amongst the rocks, and by Mr. Kermode when examining the pre-historic antiquities. From time to time I have been enabled to take part with Mr. Kermode in the examination or exploration of some of the early Manx remains.

FIG. 11. Shore collecting at Fleshwick
[*Photo. by Prof. F. J. Cole.*

The most notable of these occasions was when, some twelve years ago, we excavated the large circle of stone cists on the Meayll Hill above Port Erin, and the foundations of the neighbouring hut villages. The paper that we wrote on the results of our digging has now been long out of print, and the

single copy at Port Erin has been frequently consulted and taken out on loan. Consequently, we have now been induced, by many demands from our students and from visitors at the Biological Station, to reprint our former paper, with considerable additions, so that it may constitute an illustrated guide to the more important of the ancient monuments and other remains on the island—and in this form it will be found appended to the present Report" (18th Report, for 1904).

The Report contains also some interesting biological observations, such as Dr. Ashworth's discovery of young specimens of the curious partly parasitic Copepod *Monstrilla* in specimens of the small tubicolous worm *Salmacina* obtained on the ruined breakwater, the finding by Mr. A. D. Imms of a pseudo-scorpion *Obisium maritimum* which has otherwise only been recorded from the coast of Devon, the report by Mr. A. Scott on the fish eggs and larvæ obtained in the Port Erin tow-nettings, and Mr. Chadwick's careful drawings of the characters seen after each moult in the development of the lobster.

Twelve L.M.B.C. Memoirs—the last two being "Arenicola" by Dr. Ashworth and "Gammarus" by Miss Cussans—had now (1904) been published and another dozen or so (most of which have since appeared) were announced as in progress. This series of detailed studies of useful common types seems to be meeting with general approval in University laboratories.

The 19th Annual Report (1905) contained the second (revised and enlarged) edition of the "Guide to the Aquarium," and it may be noted that this year the number of visitors had increased to over 13,000. We may fairly claim that by means of the exhibition tanks and the Aquarium Guide our Institution is doing some educational work in spreading a knowledge of marine biology and encouraging nature-study amongst the inhabitants and summer visitors of an important sea-side resort. The total number of visitors to the Aquarium from August, 1902, to November, 1919, is 204,553.

This year saw the commencement of the bio-chemical work by a team of investigators under the leadership of Professor Benjamin Moore, which has been continued at intervals ever since and has resulted in the publication of a number of interesting papers in the Proceedings of the Royal Society and in the Bio-Chemical Journal. The earlier work dealt with the effect of slight changes in the alkalinity of sea-water in the nuclear division and embryonic development of marine animals, and later investigations included experiments in photosynthesis and in the nutrition of marine animals.

It may be appropriate to add that the Report for this year contained a description of the new Zoology Buildings of the University of Liverpool and of the proceedings that took place at the formal opening by the Earl of Onslow (then President of the Board of Agriculture and Fisheries) when Sir John Murray gave a short address on Oceanography in the Zoology Lecture Theatre. These buildings have constantly been the Liverpool centre of all our work from that time up to the present, and will continue to be so as the seat of the Oceanography department which takes over our work.

The following year, 1906, is noteworthy as being the first in which I tried the experiment of having a small steam yacht of my own at Port Erin during the summer, constantly employed in making collections and taking observations at sea. This proved so successful that the practice was extended in the following year to the Easter vacation as well as the summer, and the work from the successive yachts* ("Madge," "Ladybird" and "Runa"), in which I was most ably assisted by various friends, colleagues and senior students, was kept up with great activity until the year of the war, and to a

* To avoid any misunderstanding in the future and to correct certain erroneous reports, I think it best to state definitely once for all that these yachts were my own private property, and although used freely for the service of the Biological Station and to help the work of the Manx Fishery Board they were run entirely at my own expense. It has been a pleasure and a privilege to be able to help on the work in this manner; but this personal statement seems necessary in view of ill-informed newspaper reports.

considerable extent took the place of our earlier dredging expeditions in hired steamers. In this first year of such work I had chartered a small steam vessel, the "Madge," which lay at moorings in Port Erin Bay during the summer and was

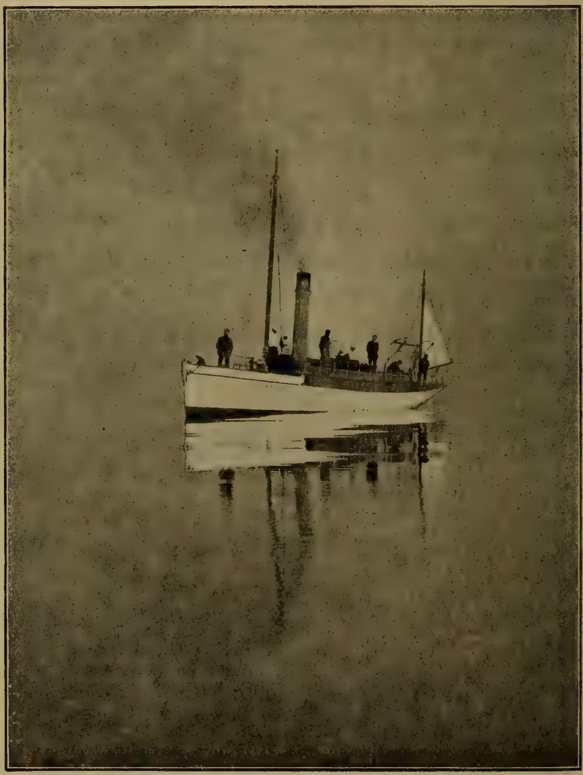


Fig. 12. S.Y. "Ladybird" on a Plankton cruise at Easter, 1908.

[*Photo. by Edwin Thompson.*

used almost daily in suitable weather for dredging expeditions in the neighbourhood, and more especially for taking a series of plankton observations with various kinds of tow-net at different fixed stations periodically and as frequently as possible.

This led in the following year to a systematic investigation which we called the "Intensive Study of the Plankton," and which has been continued from 1907 onwards to the present time, annual accounts of the results being given in the Lancashire Sea-Fisheries Reports. The chief results of the plankton gatherings made in the summer of 1906 from the "Madge" are given by Mr. Andrew Scott in an Appendix to this 20th Report.

We find in the Curator's report for 1906 that 15,000 visitors paid for admission to the Aquarium at the Biological Station. This brings up the total number of visitors admitted during these four years since the opening of the new Station to over 50,000. Amongst many animals of interest which are recorded as having appeared spontaneously in our Aquarium tanks during this or succeeding years may be noted the following:—large colonies of *Halichondria panicea* up to 16 inches by 8 inches, the compound Tunicate *Botryllus smaragdus*, the beautiful tube-building Polychæt worm *Sabella pavonia*, extensive colonies of the Hydroid *Podocoryne carnea*, multitudes of the Medusoid *Sarsia tubulosa* (probably derived from a species of *Syncoryne* growing in quantity in the suction pipe through which the supply of water is drawn from the sea), the Polyzoon *Pedicellina cernua* in colonies of large extent, and dense aggregations of the little tubicolous worm *Filograna implexa*—these being in addition of course to the many kinds of Invertebrates and Fishes which are captured and placed in the tanks by the Curator and his Assistant.

The success of the work done at sea from the small chartered steamer "Madge" during the summer of 1906 led to the purchase early in 1907 of the S.Y. "Ladybird" (36 tons and about 70 feet over all), which was constantly at work during the Easter and summer vacations of this and the following three years. This yacht proved very suitable for our work and was fitted up with a dredging derrick forward and a

full equipment of tow-nets and small fish trawls of various kinds which were worked over the stern. She was also provided with a Lucas sounding machine, an Ekman current meter, and the usual water bottles and deep-sea thermometers, which were worked over the rail amidships. The plankton results are given in considerable detail in the Report for this year.

FIG. 13. Equipment of Plankton nets, etc., on board the "Ladybird."
[*Photo. by Mr. R. Okell.*

During this and following years Professor B. Moore and Dr. Roaf continued their researches in various departments of Bio-chemistry, including the digestive ferments of invertebrates, the secretion of the hypobranchial glands of Mollusca and the bio-chemistry of the blood and other tissues of Pecten.

Notable additions to the local fauna exhibited in the Aquarium were the Lucernarian *Haliclystus auricula*, the Anemones *Aureliana augusta*, *Corynactis viridis*, *Sagartia rosea*, *S. herdmani*, *Bunodes thallia*, *Stomphia churchiæ* and a young *Cerianthus*, and the beautiful little coral *Paracyathus pteropus*.

Lobster culture was started in the Hatchery in the summer of 1907. Some thousands of larvæ were hatched and set free in their first and second stages and about 80 were reared to the lobsterling stage. This work has been continued in each successive year up to the present, and many experiments have been made by the Curator and his assistant as to the best methods of keeping the adult "berried" lobsters, and of rearing and feeding the larvæ, which will be found recorded in the various Annual Reports.

Mr. F. H. Gravely from the University of Manchester made notable faunistic investigations during the summer of 1907 and added many rare and interesting forms to our list, including the Tornaria larva of *Balanoglossus* which we have never succeeded in finding in the adult condition. Mr. Gravely eventually contributed a useful Memoir on "Polychæt Larvæ" to our series.

In the following Report, for 1908, we published a full description of the hatchery arrangements, the circulation of the water, the mechanism of the hatching-boxes by means of which they are alternately raised and then depressed through a few inches so as to keep their contained eggs in constant motion, the method of filtering the water and other details. From this time onwards the work in the Hatchery went on steadily year by year, plaice being dealt with during the spring, February to May, and lobster larvæ being reared during the summer, July to September. The numbers of millions of plaice and of thousands of young lobsters have varied from year to year (up to about eight million plaice and five thousand lobsters), and the whole of the work must still be regarded as experimental, as an attempt to find out what are the best conditions under which such operations can be carried on, and what measure of success it can be reasonably hoped to attain. On one point, however, there can be no doubt, and that is that the young fish hatched under artificial

conditions are no weaklings but are perfectly capable of growing up to the adult state and of producing young in their turn. Later on, in the year 1917, we recorded that "we now have fish producing fertile spawn, which were themselves hatched and reared in our Institution three years ago. There are about 20 of these belonging to the hatching season of 1914, and, therefore, now just three years old, and measuring on the average 10½ inches in length, which have been kept separate since the summer of 1914, and this is probably a record both as to the small size and the young age at which the plaice can spawn; and it is also probably the first time that the second generation of this fish has been produced and reared in captivity." Three generations of the fish were living in our hatching tanks in 1918, under Mr. Cregeen's careful management.

During these same years, from 1907 onwards, we had one or other of the yachts, "Ladybird" and "Runa," constantly at work during the Easter and summer vacations in the seas around Port Erin, and each of the Annual Reports for this period will be found to give details of the various kinds of experimental nets used and the results obtained in the intensive study of the plankton. The following passage may be quoted from the Report for 1908 as giving some idea of the complexity of the causes of the very marked variation in the abundance and nature of the plankton from time to time:—

"It is clear that some of the great seasonal variations in the plankton are not due to changes in the sea-water such as are recognised in hydrographic observations, but are caused simply by the normal sequence of stages in the life-histories of organisms throughout the year. No amount of 'hydrographic' change in the water will determine the presence of Echinoderm larvæ at a time of year when they are not produced, nor of Crab Megalopas when they do not naturally occur.

"Three factors, at least, contribute to the constitution of the plankton from day to day throughout the year:—

(1). The sequence and periodicity of stages in the life-history of the organisms ;

(2). Irregularities due to the inter-action of organisms, as when one group serves as the food of another ;

(3). Periodic changes and abnormalities of either time or abundance caused by the nature of the sea-water or by weather conditions which may either determine or prevent the normal or permit of an abnormal development of certain species.

"The appearance of swarms of Balanoid Nauplii, followed after an interval by the 'Cypris' stage, is an example that comes under the first head. The disappearance of Diatoms when used as food by the increasing swarms of Copepoda and other Crustacea, both larval and adult, and of the Copepoda in turn when eaten by the developing post-larval fish, are changes falling under the second head. The great increase in the number of Diatoms in spring, when the physical condition of the sea-water has become favourable, the enormous development of Dinoflagellates which may take place suddenly in autumn under unusual weather conditions, the almost total suppression of a group such as the Medusae in some localities in an unusually stormy summer, and the immigration of a species or a group of species from the open ocean or from a neighbouring sea-area as the result of variations in the hydrographic conditions, are all examples that may be classed in the third category.

"Two or all of these factors may, however, be at work together, and so the explanation of any particular change may be a very complicated problem. The increased development of a group, or the immigration of a species, may so disturb the balance of nature as to be followed by unusual changes in other groups."

It would be very difficult to summarise all the plankton results obtained during the past thirteen years—when some

6,000 hauls have been taken, carefully analysed, and the results fully discussed in a series of special reports on this "Intensive Study of the Plankton" which have been laid before and published by the Lancashire Sea-Fisheries Committee.

The following instance gives an example of local distribution of an organism in swarms, and of the erroneous conclusions that might be drawn from imperfect or incomplete observations:

"We were fortunate enough on one occasion to obtain incontrovertible evidence of the sharply defined nature of a shoal of organisms, forming an instructive example of how nets hauled under similar circumstances a short distance apart may give very different results. On the evening of April 1st (1907), at the 'alongshore' Station III., north of Port Erin, off the 'Cronk' one mile out, I took six simultaneous gatherings in both surface and deeper waters. Two of the nets were the exactly similar surface tow-nets which I have called B and C. At half-time, as the result of a sudden thought I hauled in B, emptied the contents into a jar, and promptly put the net out again. This half gathering was of very ordinary character, containing a few Copepoda, some Diatoms and some larvæ, but *no Crab Zoëas*. At the end of the 15 minutes, when all the nets were hauled on board, all the gatherings, including B, showed an extraordinary number of Crab Zoëas rendering the ends of the nets quite dark in colour. B was practically the same as C although B had only been fishing for seven minutes. It was evident that at about half-time the nets had encountered a remarkable swarm of organisms which had multiplied several times the bulk of the catch and had introduced a new animal in enormous numbers. Had it not been for the chance observation of the contents of B at half-time, it would naturally have been supposed that, as all the nets agreed in their evidence, the catches were fair samples of what the water contained over at least the area traversed—whereas we now know that the Zoëas were confined to at most the latter half of the traverse

and may have been even more restricted. Under these circumstances, an observation made solely in the water traversed during the first seven minutes would have given a very different result from that actually obtained ; or, to put it another way, had two expeditions taken samples that evening at what might well be considered as the same station, but a few hundred yards apart, they might have arrived at very different conclusions as to the constitution of the plankton in that part of the ocean."

"The Nauplius and Cypris stages of *Balanus* form an interesting study. The adult Barnacles are present in enormous abundance on the rocks of Bradda Head, and they reproduce in winter, at the beginning of the year. The newly-emitted young are sometimes so abundant as to make the water in the shore pools appear muddy. The Nauplii first appeared in 1907 in the bay gatherings on February 22nd (in 1908 on February 13th), and increased with ups and downs to their maximum on April 15th. and then decreased until their disappearance on April 26th. None were taken at any other time of the year. The 'Cypris' stage follows on after the Nauplius. It was first taken in the bay on April 6th, rose to its maximum on the same day with the Nauplii, and was last caught on May 24th. Throughout, the 'Cypris' curve keeps below that of the Nauplius, the maxima being 1,740 and 10,500 respectively. Probably the difference between the two curves represents the death-rate of *Balanus* during the Nauplius stage."

Our reports for the last twelve years fall naturally into two categories—the pre-war series which, from 1907, are largely occupied by the plankton investigations, increasing in intensity and in the variety of experimental nets made use of year by year, and, secondly, the four reports from 1915 onwards which, on account of the restrictions necessarily put upon our work at sea, were devoted in part to laying before our fellow workers and students short oceanographic studies upon the three

British pioneers Edward Forbes, Wyville Thomson and John Murray, and a final discussion of some recent bio-chemical results as affecting the metabolism of the seas in our own neighbourhood.

It will not be necessary to refer to each of these reports in detail, but it may be noted that those for 1909 and the few following years record various investigations, both morphological and physiological, undertaken by some of our younger adherents, such as Dr. W. J. Dakin, Dr. J. Pearson, Mr. W. Riddell, Mr. R. D. Laurie and Dr. H. E. Roaf.

In 1910 we added a new research wing to the building, measuring 44 feet by 18 feet, and two storeys high, which provided a useful tank room on the ground floor opening into the back yard, and a series of eight small work-rooms for researchers above. Our records show that we have had 419 workers in the present Biological Station since 1902; and the total number of workers from the Puffin Island days onwards has been 506.

This year is also notable as being that in which we held at Port Erin in the summer a first course of lectures, demonstrations and practical work dealing with Oceanography from both the hydrographical and biological points of view, full details of which are given in the 24th Report, and in conducting which I had the able assistance of Dr. Dakin and Dr. Roaf.

"Oceanography—the science of the sea—has for its scope the determination of the physical, chemical, and biological characters of the oceans of the world, and of the cause of those great seasonal variations in the microscopic living contents upon which depend man's supply of food from the sea, and the continuance of many human industries. There are scarcely any more wide-spread phenomena in nature, and probably none of more importance to man, than those vast periodic changes in the minute organisms of the sea, the causes of which are now being sought by oceanographers both

on exploring vessels and in the laboratories of Biological Stations and Universities of all civilised countries."

This was the year of the foundation of the great Museum of Oceanography at Monaco, and if this modern science of the sea has now reached such an advanced stage that it can be

FIG. 14. The first Oceanography class at Port Erin, August, 1910.

[*From a photo. by H. E. Roaf.*

demonstrated in a museum to the public, it is clearly desirable that it should be taught both theoretically and practically in our Universities and at Biological Stations. There must be many young biologists and other teachers who desire to learn something of the methods of investigation and the results obtained, by direct contact with the material and the apparatus

at some institution where oceanographical research is now being actively carried on.

During these years several of our younger Zoologists were working at L.M.B.C. Memoirs which have since been published. These include "Pecten" and "Buccinum" by W. J. Dakin, "Eupagurus" by H. G. Jackson, "Ligia" by C. G. Hewitt, "Cancer" by J. Pearson, "Antedon" by H. C. Chadwick, and "Eledone" by A. Isgrove. "Tubifex" our last published Memoir, by G. C. Dixon, appeared in 1915.

About this time several of our bio-chemists, including Professor B. Moore and Dr. Dakin, made elaborate investigations for the purpose of testing the figures recently put forward by Pütter and others as to the insufficiency of the plankton to serve as food for marine animals. The primary objects of these investigations were (1) to determine the amount of organic carbon present in solution in sea-water, (2) to determine the amount of the same substance present in the plankton, and (3) to estimate the amount of organic carbon required per day for the nourishment of selected marine animals. Professor Moore reported :—

"The results show conclusively that the amount of dissolved organic carbon present in the sea-water is almost negligible (lying well below one milligram per litre of water), and that Pütter's figures are very incorrect. It has also been shown that the amount of plankton normally present and distributed through the water is practically just as insufficient to provide food if the sea-water is merely filtered, as it comes, by a marine animal. Organic matter in solution and plankton together do not seem present in sufficient quantity for the nutrition of active marine animals, unless they hunt their food or frequent the zones where plankton is especially abundant."

Further work at Port Erin since has shown that, while the plankton supply as found generally distributed might prove sufficient for the nutrition of such sedentary animals

as Sponges and Ascidians, it is quite inadequate for active animals such as Crustaceans and Fishes. These latter are, however, able to seek out their food and are not dependent on what they may filter or absorb from the sea-water. This result accords well with our many observations on the irregularity in the distribution of the plankton and the corresponding variations in the occurrence of the migratory fishes which may be regarded as following and feeding upon the swarms of planktonic organisms.

Several of the reports during this period deal also with observations on the minute life found in the sand and mud of the sea-beach and its variations from time to time. Perhaps the most remarkable observation in this respect was the discovery that the Dinoflagellate *Amphidinium operculatum*, hitherto unknown in British seas, occurred from time to time in enormous profusion on certain parts of the shore at Port Erin. Although occasionally not present, it has continued to reappear since the time of its first discovery in 1911 year by year, and has been kept in quantity in the living condition in our laboratory tanks for the benefit of the students. A full account of the occurrence and the variations of this interesting organism will be found in the 25th and 26th Annual Reports. Since its discovery at Port Erin it has been found in quantity at such distant parts of the British Coast as Hoylake, Blacksod Bay, Cullercoats and Iona.

During some of the years preceding 1914, when we had the yachts "Ladybird" or "Runa" in commission during the summer vacation, it seemed desirable to extend our planktonic work northwards from the Irish Sea to the west coast of Scotland and the Hebrides. Twelve such cruises were undertaken, seven in the "Ladybird" and five in the "Runa," and the results are summarised in our Annual Reports for 1910 to 1913. These Scottish observations extend as far North as the Shetland Islands and as far West as the open Atlantic to the South-West

of Barra Head, and have yielded material for about a dozen detailed papers published by our own Society, the Linnean Society of London and elsewhere. One of the most notable of these is the report by Messrs. E. Heron-Allen and A. Earland on the Foraminifera, from which the accompanying beautiful illustrations are taken (Fig. 16). Mr. Heron-Allen also identified a series of 112 species of Foraminifera dredged off Bradda

Fig. 15. Examining the catch on the deck of the "Runa."

Head in 20 fathoms, the list of which will be found in our 28th Report. Mr. Wm. Riddell, while acting as my Scientific Assistant on the yacht, drew up with me a series of reports on the planktonic results of the cruises, which are published in the Journal of the Linnean Society.

In conclusion it is only right to point out that the series of Annual Reports which has now been briefly summarised does not adequately represent all the work carried out under

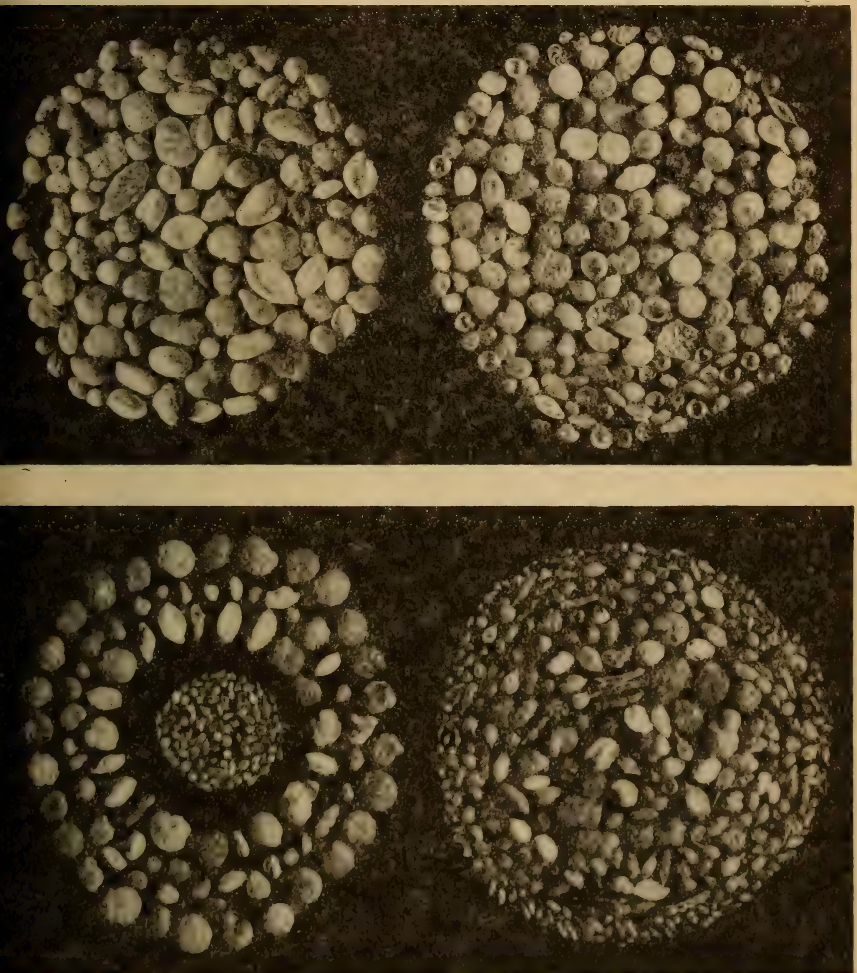


FIG. 16. Four samples of Foraminifera gatherings from dredgings off the West Coast of Scotland. [*Photo. by A. E. Smith.*

the auspices of the Liverpool Marine Biology Committee at Puffin Island, Port Erin and Liverpool during its 35 years of activity. Many of the workers in the Biological Station, in the

University laboratories or in the field have not been referred to in this brief summary, and for details of the work done reference must, of course, be made to the series of L.M.B.C. Memoirs and to the other papers of the various investigators, which are for the most part published elsewhere.

Let me add my conviction that the history of the Liverpool Marine Biology Committee has shown clearly the advantage of "team-work" in this department of science. No one man or even two or three men could undertake a marine biological survey—still less its modern extension the complete Oceanographic investigation of an area. It is only by the co-operation of many minds and hands and by the co-ordination of their varied activities that we can hope to gain that adequate and well-proportioned knowledge of the animals and the plants, and the effect upon them of their physical environment, towards which we of the Liverpool Committee hope that our work has made some contribution.

FIG. 17. S.Y. "Runa" with the "Agassiz" dredge coming up at the stern.

APPENDIX B.

List of species* recorded by the L.M.B.C. since the publication of their British Association List in 1896.

DIATOMACEA.

Asterionella japonica.
Biddulphia sinensis.
Chœtoceras contortum.
C. criophilum
C. debile.
C. decipiens.
C. densum.
C. sociale.
C. teres.
Coscinodiscus grani.
Coscinosira polychorda
Ditylium brightwelli.
Guinardia flaccida.
Lauderia borealis.
Rhizosolenia semispina.
R. stolterfothii.
R. alata.
Streptotheca thamensis.
Thalassiosira gravida.
T. nordenskioldi.
T. subtile.

SPOROZOA.

Merocystis kathae, Dakin.
Glugea stephani, Hagenm.
Sphaerospora platessa, Woodcock.
Lymphocystis johnstonei, Woodcock.
Myxobolus esmarkii, Woodcock.
Ichthyophthirius multifiliis, Fouquet.

FORAMINIFERA.

Biloculina bulloides.
Miliolina circularis.
M. seminuda.
M. candeiana.
M. laevigata.
M. brongniartii.
M. rotundata.
M. bosciana.
M. pygmaea.

Foraminifera—*continued.*

Ophthalmidium carinatum.
Cornuspira selseyensis.
Bathysiphon argenteus.
Haplophragmium pseudospirale
Textularia conica.
Spiroplecta wrightii.
Bolivina textilarioides.
Cassidulina subglobosa.
Nodosaria consobrina.
Polymorphina amygdaloides.
Discorbina mamilla.
D. praegeri.
D. obtusa.
Truncatulina variabilis.
Pulvinulina oblonga.
P. haliotidea.
Rotalia orbicularis.
R. perlucida.
Polystomella macella.
Operculina ammonoides.

DINOFLAGELLATA.

Amphidinium operculatum.

HYDROIDA.

Rhizogeton fusiformis.
Podocoryne carnea.
Cuspidella costata.
Campanularia repens.

SIPHONOPHORA.

Cupulita sarsi.

SCYPHOMEDUSAE.

Pelagia perla.

ZOANTHARIA.

Edwardsia carnea.
Ilyanthus mitchellii.

* I am indebted to Mr. Scott for the list of Diatomaceæ, which he has identified from our Port Erin tow-nettings, and for the lists of Copepoda, and some other groups of the Crustacea.

Dr. Johnstone has supplied the lists of Sporozoa and of Parasitic Worms, some of them new species, the descriptions of which will be found in the Reports to the Lancashire Sea-Fisheries Committee.

Zoantharia—*continued.*

Arachnactis albida.
A. bournei.
Aureliana augusta.
Bunodes thallia.
Stomphia churchiæ.
Peachia hastata.
Urticina eques, Gosse.
Paracyathus pteropus.
Caryophyllia smithi.

TURBELLARIA.

Polycelis nigra.
Promesostoma agile.
Mesostoma neapolitana.
Macrorhyncus croceus.
Provortex affinis.
Grafilla buccinicola.
Plagiostoma koreni.

TREMATODA.

Axine bellones.
Callicotyle kroyeri.
Dactylocotyle pollachii.
Diplectannum aequans.
Microcotyle labracis.
Onchocotyle appendiculata.
Octobothrium alosae
O. merlangi.
O. scombri.
Phyllocotyle gurnardi.
Phyllonella soleae.
Placunella pini.
Distomum valdeinflatum, Stossich.
D. appendiculatum, Rud.
D. gulosum, Linton.
D. ocreatum, Molin.
D. vitellosum, Linton.
D. mollissum, Levinsen.
D. rufoviride, Rud.
Gasterostomum gracilescens (Rud.).
Cercaria fissicauda, La Val.
Echinostomum imbutiforme, Molin.
Derogenes varicus (O. F. M.)
Allocreadium labracis (Duj.)
Zoogonides viviparus (Olsson).
Lebouria idonea, Nicoll.
Paracotyle caniculae, Johnst.
Koellikeria filicolle (Rud.).
Didymozoon scombri, Tasch.
Gyrodactylus elegans, Nordm.

CESTODA.

Dibothrium punctatum, Rud.
D. crassiceps, Rud.
Abothrium rugosum (Goetze).
Tetrarhynchus tetrabothrius, van Ben.
T. erinaceus, van Ben.

Cestoda—*continued.*

T. van benedeni (Crety).
Phyllobothrium lactuca, van Ben.
P. thridax, van Ben.
Echeneibothrium variabile, van Ben.
E. dubium, van Ben.
Oncobothrium uncinatum, Rud.
Acanthobothrium coronatum, Rud.
Calliobothrium verticillatum, Rud.
C. eschrichtii, van Ben.
Crossobothrium laciniatum, Linton.
Anthobothrium auriculatum, Rud.
A. musteli, van Ben.
Echinobothrium affine, Diesing.
Prosthecobothrium dujardinii, v. Ben.
Rhinebothrium minimum (van Ben.).
Coenomorphus linguatula (van Ben.).

CESTODARIA.

Gyrocotyle urna, Grube and Wag.

ACANTHOCEPHALA.

Echinorhynchus acus, Rud

NEMATODA.

Rhabditis sp.
Spilophora sp.
Dorylaimus sp.
Oncholaimus sp
Enoplus sp.
Plectus sp.

HIRUDINEA.

Platybdella soleae.
Trachelobdella lophii.
Pontobdella laevis (Blainv.).

GEPHYREA.

Sipunculus bernhardus.
Thalassema lankesteri.
Priapulus caudatus.

POLYCHAETA.

Syllis sp. (? young *monilaris*)
S. cornuta.
S. krohnii.
Pionosyllis lamelligera.
Odontosyllis ctenostoma.
Trypanosyllis rebra.
Autolytus incertus.
A. longisetosus.
Myrianida pinnigera.
Sphærodorum sp.
Magalia perarmata.
Polynoe reticulata.
P. semisculpta.
Notophyllum foliosum.

Polychaeta—*continued.*

Staurocephalus sp.
Ophryotrocha puerilis
Nematonereis sp.
Glycera alba.
G. lapidum.
G. siphonostomata.
Aricia cuvieri.
Scolopus (*Theodisca*) *mamillata.*
Polydora cœca.
P. flava.
Scolecolepis fuliginosa.
Chætopterus variopedatus.
Dodecaceria (? *concharum*).
Melinna cristata.
Praxilla gracilis.
Amphiglena mediterranea.
Arenicola grubii.
Eumenia sanguinea.
Potamilla reniformis.
P. torelli.
Myxicola infundibulum.
Salmacina dysteri.
Flabelligera affinis.
Gattiola finmarchica.

POLYZOA.

Mucronella peachii, var. *labicsa*
M. abyssicola.
Hippothoa flagellum.
Cylindroccium pusillum.
Pedicellina gracilis.

CRUSTACEA—BRACHYURA.

Gonoplax angulatus.
Dromia vulgaris.

MACRURA.

Athanas nitescens.
Callianassa subterranea.
Jaxea nocturna (larvæ).
Upogebia stellata.

SCHIZOPODA.

Mysis longicornis.
Schistomysis arenosa.
Erythrops erythrophthalmus.
E. serrata.
Siriella armata.

STOMATOPODA.

Squilla desmarestii (larvæ).

CUMACEA.

Eudorellopsis deformis.
Eudorella emarginata.
Campylaspis glabra.
Cumella pygmaea.
Pseudocuma similis.

ISOPODA.

Apseudes hibernicus.
Dajus mysidis.
Eurydice inermis.
E. spinigera.
E. truncata.
Gnathia dentata.
Idothea balthica.
I. granulosa.
I. pelagica.
Tanais cavolinii.

BOPYRIDÆ.

Pleurocrypta porcellanae.

AMPHIPODA.

Iphimedia eblanæ.
Stenothoë crassicornis.
Gammarus duebeni.
Halimedon parvimanus.
Normanion quadrimanus.
Argissa hamatipes.
Janiropsis breviremis.

OSTRACODA.

Cythere pellucida.
C. porcellaneæ.
C. gibbosa.
Cytheropteron humile.
Asterope mariæ

COPEPODA.

Microcalanus pusillus.
Stephus gyrans.
Candacia armata.
Pontella lobiancoi.
Stenhelia intermedia.
Ameira exilis.
A. intermedia.
Delavalia mimica.
Canthocamptus parvus.
Mesochra propinqua.
Itunella tenuiremis.
Clytemnestra rostrata.
Idya minor.
Heteropsyllus curticaudatus.
Laophonte denticornis.
Leptopsyllus herdmani.
L. intermedius.
Thaumaleus thompsoni.
Corycaeus anglicus.
Oncaea minuta.
O. subtilis.
Giardella thompsoni.
Lichomolgus hirsutipe
Hersiliodes littorali
Enterognathus comatulæ.

COPEPODA (parasita).

Nicothoe astaci.
Bomolochus soleae.
Caligus brevicaudatus.
C. diaphanus.
C. gurnardi.
C. labracis.
C. minimus.
C. pelamydis.
C. zei.
Pseudocaligus brevipedes.
Lepeophtheirus pollachii.
Trebius caudatus.
Echthrogaleus coleoptratus.
Pandarus bicolor.
Dichelestium oblongum.
Lernanthropus kroyeri.
Hatschekia labracis.
H. pygmaea.
Kroyeria lineata.
Congericola pallida.
Eudactylina acanthii.
E. acuta.
E. insolens.
Lernaea lusci.
L. minuta.
Haemobaphes cyclopterinus.
Lernœenicus encrasicola.
Trypaphylus musteli.
Chondracanthus clavatus.
C. cornutus.
C. depressus.
C. flurae.
C. limanda.
C. soleae.

Copepoda (parasita)—*continued.*

C. zei.
Medesicaste asellinum.
Thysanote impudica.
Charopinus dalmanni.
C. ramosus.
Lernaeopoda bidiscalis.
Brachiella insidiosa.
B. ovalis.
Clavella scombri.
C. paradoxa.

CHONIOSTOMATIDAE.

Sphaeronella paradoxa.

RHIZOCEPHALA.

Peltogaster paguri.

MOLLUSCA—LAMELLIBRANCHIATA

Neolepton obliquatum.

NUDIBRANCHIATA.

Doris pusilla.
D. repanda.
D. diaphana.
Galvina cingulata.
Hermaea dendritica.
Hero formosa.

PISCES.

Leptocephalus morrisii.
Lepadogaster decandollii.
Raia fullonica.
Callionymus maculatus.

This brings the total number of species recorded by the Liverpool Marine Biology Committee from their district up to about 2,500.

Dec. 16*th*, 1919. W. A. H.

APPENDIX C.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1918).

HIS EXCELLENCY THE RIGHT HON. LORD RAGLAN, Lieut.-Governor of the Isle of Man.

PROF. R. J. HARVEY-GIBSON, J.P., M.A., Liverpool.

MR. W. J. HALLS, Liverpool.

PROF. W. A. HERDMAN, D.Sc., F.R.S., F.L.S., Liverpool. Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

MR. P. M. C. KERMODE, Ramsey, Isle of Man.

PROF. BENJAMIN MOORE, F.R.S., London.

SIR CHARLES PETRIE, Liverpool.

MR. E. THOMPSON, Liverpool, Hon. Treasurer.

MR. A. O. WALKER, F.L.S., J.P., formerly of Chester.

MR. ARNOLD T. WATSON, F.L.S., Sheffield.

Curator of the Station—MR. H. C. CHADWICK, A.L.S.

Assistant—MR. T. N. CREGEEN.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The OBJECT of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The COMMITTEE shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the AFFAIRS of the Committee shall be conducted by an HON. DIRECTOR, who shall be Chairman of the Committee, and an HON. TREASURER, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any VACANCIES on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The EXPENSES of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The BIOLOGICAL STATION shall be used primarily for the Exploring work of the Committee, and the SPECIMENS collected shall, so far as is necessary, be placed in the first

instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION
AT
PORT ERIN.

General Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biology Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when

there is room, and after formal application to the Director, are :—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually ; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steamboat dredging expeditions are defrayed by the Committee, the

specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to prepare a short report upon his work—not necessarily for publication—to be forwarded to Prof. Herdman before the end of the year for notice, if desirable, in the Annual Report.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

Memoranda for Students and Others working at the Port Erin Biological Station.

Post-graduate students and others carrying on research will be accommodated in the small work-rooms of the ground floor laboratory and in those on the upper floor of the new research wing. Some of these little rooms have space for two persons who are working together, but researchers who require more space for apparatus or experiments will, so far as the accommodation allows, be given rooms to themselves.

Undergraduate students working as members of a class will occupy the large laboratory on the upper floor or the front museum gallery, and it is very desirable that these students should keep to regular hours of work. As a rule, it is not expected that they should devote the whole of each day to work in the laboratory, but should rather, when tides are suitable, spend a portion at least of either forenoon or afternoon on the sea-shore collecting and observing.

Occasional collecting expeditions are arranged under guidance either on the sea-shore or out at sea, and all undergraduate workers should make a point of taking part in these.

It is desirable that students should also occasionally take plankton gatherings in the bay for examination in the living state, and boats are provided for this purpose at the expense of the Biological Station to a reasonable extent. Students desiring to obtain a boat for such a purpose must apply to the Curator at the Laboratory for a boat voucher. Boats for pleasure trips are not supplied by the Biological Station, but must be provided by those who desire them at their own expense.

Students requiring any apparatus, glass-ware or chemicals from the store-room must apply to the Curator. Although the Committee keep a few microscopes at the Biological Station, these are mainly required for the use of the staff or for general demonstration purposes. Students are therefore strongly advised, especially during University vacations, not to rely upon being able to obtain a suitable microscope, but ought if possible to bring their own instruments.

Students are advised to provide themselves upon arrival with the " Guide to the Aquarium " (price 6d.), and should each also buy a copy of the set of Local Maps (price 2d.) upon which to insert their faunistic records and other notes.

Occasional evening meetings in the Biological Station for lecture and demonstration purposes will be arranged from time to time. Apart from these, it is generally not advisable that students should come back to work in the laboratory in the evening ; and in all cases all lights will be put out and doors locked at 10 p.m. When the institution is closed, the key can be obtained, by those who have a valid reason for entering the building, only on personal application to Mr. Chadwick, the Curator, at 3, Rowany Terrace.

REGULATIONS OF THE EDWARD FORBES EXHIBITION.

[Extracted from the *Calendar* of the University of Liverpool for the Session 1915-16, p. 438.]

"EDWARD FORBES EXHIBITION.

"Founded in the year 1915 by Professor W. A. Herdman, D.Sc., F.R.S., to commemorate the late Edward Forbes, the eminent Manx Naturalist (1815-1854), Professor of Natural History in the University of Edinburgh, and a pioneer in Oceanographical research.

The Regulations are as follows :—

(1) The interest of the capital, £100, shall be applied to establish an Exhibition which shall be awarded annually.

(2) The Exhibitioner shall be a post-graduate student of the University of Liverpool, or, in default of such, a post-graduate student of another University, qualified and willing to carry on researches in the Manx seas at the Liverpool Marine Biological Station at Port Erin, in continuation of the Marine Biological work in which Edward Forbes was a pioneer.

(3) Candidates must apply in writing to the Registrar, on or before 1st February.

(4) Nomination to the Exhibition shall be made by the Faculty of Science on the recommendation of the Professor of Zoology.

(5) The plan of work proposed by the Exhibitioner shall be subject to the approval of the Professor of Zoology.

(6) Should no award be made in any year, the income shall be either added to the capital of the fund, or shall be applied in such a way as the Council, on the recommendation of the Faculty of Science, may determine.

(7) The Council shall have power to amend the foregoing Regulations, with the consent of the donor, during his lifetime, and afterwards absolutely; provided, however, that the name of Edward Forbes shall always be associated with the Exhibition, and that the capital and interest of the fund shall always be used to promote the study of Marine Biology."

Edward Forbes Exhibitioners.

1915	Ruth C. Bamber, M.Sc.
1916	E. L. Gleave, M.Sc.
1917	C. M. P. Stafford, B.Sc.
1918	Catherine Mayne, B.Sc.
1919	George Frederick Sleggs, B.Sc.

Appendix D.

HON. TREASURER'S STATEMENT.

The Balance Sheet and List of Subscribers are shown on the following pages. It will be noticed that there is a credit balance to hand over to the Liverpool University at the end of the present year.

The following is a copy of the Minutes of the Meeting at which it was decided that the Liverpool Marine Biology Committee should be taken over by the Liverpool University:—

Minutes of Meeting held at
Manesty Buildings, College Lane, Liverpool.
Tuesday, March 11th, 1919.

At a Meeting of the Liverpool Marine Biology Committee held as above, the following were present:

Professor W. A. Herdman, in the Chair.
Mr. Edwin Thompson, Hon. Treasurer.
Mr. W. J. Halls.
Lt.-Col. R. J. Harvey Gibson.

1. Letters were read from Mr. A. O. Walker, Mr. P. M. C. Kermode, and Mr. Arnold T. Watson, apologising for absence, and expressing cordial agreement with the proposal to transfer the property of the Liverpool Marine Biology Committee to the University of Liverpool for the use of the Department of Oceanography.

2. It was moved by Professor Herdman, seconded by Mr. Edwin Thompson, and carried unanimously:—

"That, considering that a Department of Oceanography (under an endowed professorship) has now been established at the University of Liverpool for the purpose of con-

tinuing and extending the work in marine biology and fisheries research which the LIVERPOOL MARINE BIOLOGY COMMITTEE was founded to promote, the Members of the Committee now assembled are of the opinion that the time has come when the intentions of the founders can best be fulfilled by handing over the vested interests and the property of the Committee, as stated in the appended Schedule, to the University on the understanding that the University, by means of the Department of Oceanography, will continue to promote higher education and research in Oceanography, including marine biology and its applications to the fishing industries, at the Port Erin Biological Station and in Liverpool; and they hereby resolve to carry out this intention forthwith, the accounts to be made up to September 30th,* 1919, and the property to be made over to the University on that date."

SCHEDULE

The lease of the Port Erin Biological Station.

The apparatus, books, chemicals, and other property of the LIVERPOOL MARINE BIOLOGY COMMITTEE at Port Erin.

The apparatus, books, etc., of the LIVERPOOL MARINE BIOLOGY COMMITTEE in the Zoological Department of the University and at the publishers.

The investments and other funds of the Committee.

3. The hope was expressed that the University would recognise the right of the scientific former Members of the LIVERPOOL MARINE BIOLOGY COMMITTEE (Mr. W. J. Halls, Professor Harvey Gibson, Professor Herdman, Mr. P. M. C.

* This date was subsequently, by agreement with the University, altered to December 31st.

Kermode, Professor B. Moore, Mr. Edwin Thompson, Mr. A. O. Walker, and Mr. Arnold Watson) to continue to make occasional use of the Port Erin Laboratory free of charge; and would retain the right of all the Biological Departments of the University to send Senior Students and post-graduate research workers to occupy a University "Table" at the institution.

4. It was resolved to send a copy of these Minutes to each Member of the LIVERPOOL MARINE BIOLOGY COMMITTEE and to the Vice-Chancellor of the University.

[*End of Minutes.*]

In accordance with the decision minuted above the affairs of the Committee will be taken over by the University as from January 1st, 1920.

In concluding this Statement as Hon. Treasurer may I be permitted to direct attention to the letter signed by Prof. Herdman and myself which is issued with this Report, and to express the hope that our subscribers who have done so much for us in the past will continue to give their support to the Port Erin Biological Station.

EDWIN THOMPSON,
Hon. Treasurer.

"Woodlands,"
13, Fulwood Park,
Liverpool.

December 16*th*, 1919.

SUBSCRIBERS.

	£	s.	d.
Browne, Edward T., M.A., Anglefield, Berkhamsted, Herts.	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, J. F. L., M.P., 43, Harrington Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Dale, Sir Alfred, University, Liverpool	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Gibson, Prof. R. J. Harvey, The University, Liverpool	1	1	0
Graveley, F. H., Indian Museum, Calcutta ...	0	10	6
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holt, Dr. Alfred, Dowsefield, Allerton	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Isle of Man Natural History Society	2	2	0
Jarmay, Sir John, Hartford, Cheshire	1	1	0
Livingston, Charles, 16, Brunswick-st., Liverpool	1	1	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., Tower Buildings, Liverpool...	0	10	0
Mond, R., Sevenoaks, Kent...	5	0	0
Monks, F. W., Warrington...	2	2	0
Muspratt, Dr. E. K., Seaforth Hall, Liverpool ...	5	0	0
Petrie, Sir Charles, Oakfield, Aigburth, Liverpool	1	1	0
Rathbone, Miss May, Backwood, Neston	1	1	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	1
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Smith, A. T., 43, Castle-street, Liverpool... ...	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Forward	£42	8	7

	£	s.	d.
Forward... ...	42	8	7
Thomas, Dr. Thelwall	1	1	0
Thompson, Edwin, 13, Fulwood Park, Liverpool ...	1	1	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Ward, Dr. Francis, 20, Park Road, Ipswich ...	2	2	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
Whitley, Edward, Oneida, Sefton Park, Liverpool	2	2	0
	£56	11	7
Add old Subscriptions received *less* Subscriptions still unpaid	5	5	0
	£51	6	7

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

	£	s.	d.
Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
Prof. Moore	10	0	0
	£40	0	0

DONATIONS.

	£	s.	d.
Hutton, J. A., Woodlands, Alderley Edge ...	5	0	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
	£6	1	0

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. In Account with EDWIN THOMPSON, Hon. Treasurer. **Cr.**

1919.	£	s.	d.
To Printing and Stationery	28	16	4
,, Boat Hire	5	13	0
,, Books, Apparatus and Supplies at Port Erin Biological Station	17	19	7
,, Postages, Carriage, &c.	7	14	4
,, Salary—Share of Curator's	85	0	0
,, ,, ,, Assistant's	49	7	3
,, Sundries	8	8	4
,, Balance in hand, December, 1919	2	10	7
	£205	9	5

1919.	£	s.	d.
By Balance in hand, December, 1918	2	17	0
,, Subscriptions and Donations received	57	7	7
,, Amount received from Universities for hire of "Work Tables"	40	0	0
,, Laboratory Fees	5	18	8
,, Interest on British Association (1896) Fund	28	0	0
,, Interest on Investment	6	18	7
,, Sale of Guides and Post Cards	22	1	9
,, ,, Specimens, &c.	31	18	10
,, Bank Interest	10	7	0
	£205	9	5

Endowed Invested Fund:—
British Workman's Public House Co. 99 Shares £1 each fully paid.

	£	s.	d.
Memoir Fund—Balance, as at December, 1918	212	1	7
Add Sales of Memoirs	17	2	9
	£229	4	4
Extension Fund:—Balance, as at December, 1918	£37	4	9
Board of Agriculture and Fisheries Account—			
Balance December, 1918	156	12	7
Fisheries Research Work Expenditure	65	9	1
	£91	3	6

EDWIN THOMPSON,
Hon. Treasurer.

Audited and found correct,
COOK & LEATHER,
Chartered Accountants.

Liverpool, *December 18th, 1919.*

NOTE ON THE HAND SKELETON OF SOME CETACEAN FOETUSES.

By Stanley T. Burfield, B.A. Cantab.,

Lecturer in Zoology, Liverpool University.

The Cetacean fore-limb has formed the subject of a number of researches. Taking as a starting point the almost universally accepted assumption that the Cetacea have been evolved from land-living mammals, the changes which have been brought about in the derivation of the balancing and guiding flipper* from the typical pentadactyl arm and hand of the land-livers, form a fascinating study.

The main lines of the adaptation of the pentadactyl fore-limb to the aquatic habit may perhaps be restated. The humerus is short but freely articulated at its joint with the shoulder girdle. The flipper as a whole moves about this joint, and all the remaining joints in the fore-limb are imperfect. The radius and ulna are flattened, and these bones, together with the wrist and digits, are bound together to form a single smooth-surfaced " fin " or flipper. In the production of this fin-like fore-limb the digits are often spread out, and the number of phalanges has been increased (Hyperphalangy). This latter phenomenon is shown in a still more marked degree by the Ichthyosauria, the adaptation in this case having been likewise brought about, it is believed, in the derivation of a fin or flipper from a typical pentadactyl fore-limb of some land-living reptiles. This similar adaptation in two such widely separated groups as the Cetacea and Ichthyosauria exhibits

* It is probable that the flipper was, in the first instance, a swimming paddle relatively larger than is now seen in the living Cetacea. With the taking over of the propulsion by the tail, the flipper became relatively smaller and retained only the function of guiding and balancing as in the pectoral fin of fish.

a beautiful case of the phenomenon of convergence. A third method which has been adopted for giving an increased surface to the flipper is well shown in the Ichthyosauria. This consists in the splitting of the fifth digit into two.

With regard to the observed number of digits there is a difference in the two large groups of whales—toothed whales and whalebone whales. The toothed whales have five digits. The whalebone whales are generally said to have four digits, except *Balaena*, the Right Whale, which has five. The matter does not seem quite as simple as this, however. In the Rorquals (*Balaenopteridae*) there is often present a small element which has been considered to be a vestigial thumb (digit No. 1). This is followed by four well-marked digits, each exhibiting hyperphalangy, digits No. 3 and 4 in this series having six, seven, or even eight phalanges each.

Kükenthal* made a detailed study of the flipper skeleton in a number of foetuses both of toothed and whalebone whales, and discovered some new facts which are of considerable importance in the interpretation of the hand skeleton of these forms. Since this paper the only author who has published a paper of any great importance on the subject is Kunze†, though various authors have quoted Kükenthal with more or less approval.‡

Some flippers from small whale foetuses have come into my possession, and on examination they show very clearly an interesting condition found by Kükenthal. Since small whale foetuses are not easily obtained, I have considered the specimens of sufficient interest to warrant their exhibition to the Society, accompanied by a short note on the general phenomena shown by them.

* Kükenthal, W. "Walthiere" in *Denkschr. Med. Nat. Gesells.* Jena, 1889-93.

† Kunze, A. *Zool. Jahrb. Anat.* Vol. 32, p. 577.

‡ *e.g.*, Allen, G. M. *Mem. Boston Soc. Nat. Hist.* Vol. 8, No. 2, 1916. p. 191.

The flippers exhibited were as follows :—

	Species.	Approx. length of foetus.	Flippers shown.
A.	*Balaenoptera physalus** (Linn.).	21·3 cms.	Right and Left
B.	Do.	42·6 cms.	do.
C.	*Delphinapterus* (*Beluga*) *leucas*, Pall.	15 cms.	Right.

The skeletons were exhibited by dehydrating the whole flipper in absolute alcohol, and then clearing in cedar oil and examining by strong transmitted light.

Balaenoptera physalus (Linn.).

Foetuses *A*. and *B*. show a vestigial cartilage lying between the second and third digits of the well-marked series of four. The condition shown in *A*. is very similar to that described by Kükenthal from a considerably larger foetus. Foetus *B*. also shows the vestige, but in this case only a very small nodule remains.

Kükenthal made the interesting suggestion that these bodies, which in the better developed condition are distinctly composed of two or three segments, are the vestiges of a digit (No. 3) which has dropped out from the more generalised pentadactyl hand. This suggestion was supported by a consideration of the nerves supplying the fingers. If this interpretation be correct, the condition is unique among mammals. It is well known that in all other mammals in which there is a reduction of the number of digits, the most persistent digit of the series is No. 3, which may alone remain, as in the horse. On this interpretation the small nodule usually considered to represent digit No. 1 must represent a prepollex.

* This is the common "Finner" whale, usually called *B. musculus*. For the alteration of the name on the rules of priority see True, F. W., *Proc. U. S. Nat. Mus.* Vol. XXI, p. 621.

Delphinapterus leucas, Pall.

Kükenthal has shown that this species exhibits another phenomenon in the hand skeleton. This consists in the longitudinal splitting of digit No. 5. The condition shown in Foetus *C.* is interesting in this connection. This foetus is quite a small one, but the digit No. 5 does not show any signs of the splitting as described by Kükenthal. Digit No. 4, however, shows a well-marked branch, lying between this digit and digit No. 5. The branch springs from the first phalanx, and itself consists of four well-marked phalanges.

EXPLANATION OF PLATE

Fig. 1. *Balaenoptera physalus* (Linn.).
Foetus *A*. Left Pectoral Fin. × 4.

Fig. 2. *Balaenoptera physalus* (Linn.).
Foetus *A*. Right Pectoral Fin. × 4.

Fig. 3. *Balaenoptera physalus* (Linn.).
Foetus *B*. Right Pectoral Fin. × 2.

Fig. 4. *Delphinapterus leucas*, Pall.
Foetus *C*. Right Pectoral fin. × 4.

I-V = Digits Nos. one to five; Br. = Branch of Digit No. IV; pi = pisiform; pp = prepollex; r = radius; u = ulna.

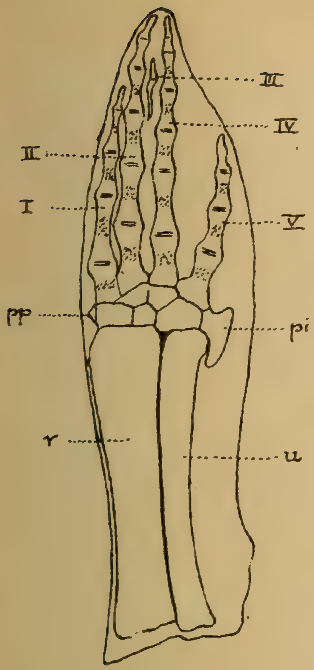


FIG. 1.

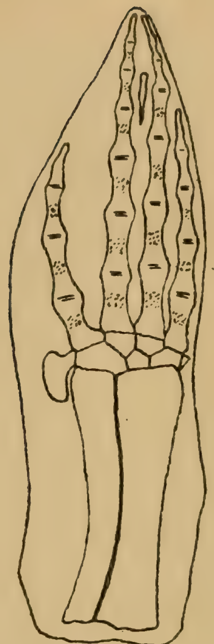


FIG. 2.

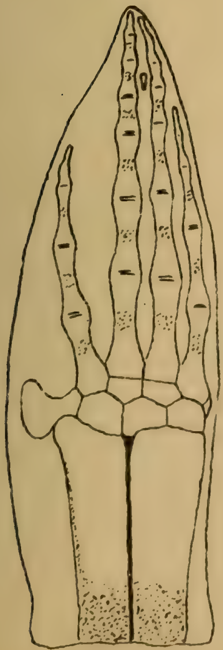


FIG. 3.

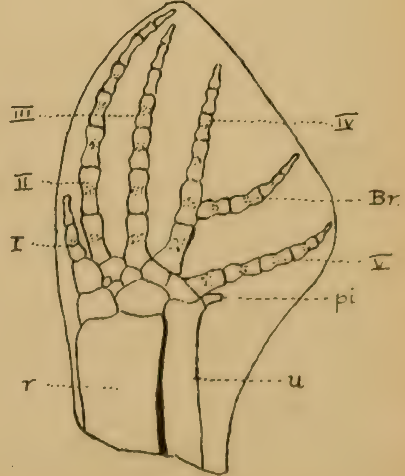


FIG. 4.

REPORT ON THE INVESTIGATIONS CARRIED ON DURING 1919 IN CONNECTION WITH THE LANCASHIRE SEA-FISHERIES LABORATORY AT THE UNIVERSITY OF LIVERPOOL, AND THE SEA-FISH HATCHERY AT PIEL, NEAR BARROW.

EDITED BY

Professor W. A. HERDMAN, C.B.E., F.R.S.,

Honorary Director of the Scientific Work.

(With Text-Figures.)

Contents.

INTRODUCTION.

Last year in the Editorial Introduction to the Report it was pointed out that I was writing for the last time as Professor of Zoology in the University of Liverpool; and now, as Professor of Oceanography for one year, I have the honour to submit to the Committee the last Annual Report on the Scientific Fisheries work in which I can appear as editor or compiler. Dr. James Johnstone succeeds me as Professor of Oceanography on October 1st, 1920, and into his capable hands passes the production of these reports from that time onwards.

I have now drawn up or edited twenty-eight of these Reports—since 1892 when, under the chairmanship of Mr. John Fell, the Committee appointed me Honorary Director of the scientific work and invited me to report annually upon the sea-fisheries investigations carried on in the district. I trust that these reports may be regarded by the Committee as having done something towards making known the scientific conditions of the fisheries under their charge, and as having made some contribution to the knowledge of those fundamental problems of life in the sea that must underlie all rational exploitation and administration of a sea-fisheries district.

The programme of re-construction of our scheme of Sea-fisheries investigation which was foreshadowed in the last report is slow in coming into full operation ; but still something has been done during the past year. Scientific work at sea has been resumed, the staff has been increased and plans have been made for much further work. With the support and co-operation of the Committee, the department of Oceanography in the University has been fully established, lectures and practical work in the laboratory have commenced and several students are now in training and will no doubt in due course be available to fill fisheries posts at home or abroad. It is clear that the need exists for such scientifically trained men. There is evidence from the Government Departments, from the Dominions and Colonies over-seas and from the more enlightened and progressive branches of the industry itself that more fully-trained workers are urgently required, and that all progress in the future will depend upon the advance side-by-side of Sea-fisheries EDUCATION and INVESTIGATION. I dealt so fully with the details of what is desirable under these two heads in my memorandum on Fisheries Reconstruction and Fisheries Research last year that I need not repeat my remarks nor elaborate the matter further, but would respectfully urge members of the Committee to refer again in this

connection to these sections of last year's Report—remembering that if Great Britain is to continue to hold her high place in the fisheries of North-West Europe it can only be by the provision of higher education and more scientific knowledge for those intending to enter commercial life in connection with Sea-fisheries, and by arranging for a closer co-operation between the scientific experts and those carrying on the industry.

It is appropriate that Lancashire, and especially Liverpool, should give a lead to the country in providing such higher scientific sea-fisheries education, and it may be useful to place on record that the Oceanography Department in the University has now made a start with its work and has already enrolled a few students who are engaged in advanced studies. The University has arranged to provide two curricula in connection with this Department, both having special reference to training for fisheries posts, either as investigators or as commercial men. The one leads to a B.Sc. degree in Oceanography and Fisheries Science, the other to the degree of Bachelor in Commercial Science with special reference to a business or administrative career in connection with the fishing industries. As these are probably the first University curricula definitely arranged for degrees in Fisheries Science in this country, it may be well to state here the following further details :—Both are three years' curricula, with the possibility of a fourth year for those who have the time and ability to take an Honours degree*. The course for the degree of B.Sc. consists in the first year of the preliminary sciences—Chemistry, Physics and Biology, which are fundamental to all further work in Science or the applications of science to industry. Then follows the "Intermediate" examination, and after that the student has two years of further training in selected branches of Science leading up to the "Final" examination. In the first of these

* For full details and regulations see the *Calendar* of the University of Liverpool.

years he takes Zoology, Bio- and Physical Chemistry, Geology and Oceanography. In his last year he continues to study Zoology, Chemistry and more advanced Oceanography, consisting of a general course along with three special subjects, one of which has to be selected by the student, viz., Marine Biology, Marine Geology, and Sea-Fisheries.

The course for the B.Com.Sc. degree consists of one year of preliminary studies preparatory to the Intermediate examination and then two years leading up to the Final. The first of these is occupied by the principles of Economics and Commerce, a modern language, Marine Biology and a general course on Oceanography. The work in the final year consists in the study of commercial transactions, a continuation of the same modern language, and the detailed study of a selected industry, such as Sea-Fisheries.

The University has established in connection with the Department of Oceanography an "Advisory Committee" upon which they have appointed the Chairman (Mr. Charles MacIver) and the Superintendent (Dr. J. Travis Jenkins) as representing your Committee, along with representatives of the Isle of Man Fishery Board, the Liverpool Marine Biology Committee, the Scientific Staff of the University and some of the leading fishing industries of the neighbourhood. It is hoped that in this way all these cognate interests may be brought into close relation with the scientific work of the Oceanography department.

In the present Report we have a paper from Dr. Johnstone on some vermean parasites and abnormalities of fishes, and another on the dietetic value of herrings, especially in relation to their times of spawning. There are contributions by Mr. Walton, who worked for some time during the year on our staff, dealing with the ecology of cockle-beds in the district, and two papers by Mr. R. J. Daniel, who has come back to us after his war service, the one dealing with our drift-bottle

experiments and the other discussing the observations on the periodicity in the abundance of plaice. Mr. Scott has two notes, one on an invasion of the Barrow Channel by *Pleurobrachia* and *Noctiluca*, the other on the stomach contents of some mackerel from Port Erin; and finally, with the help of Miss Lewis and Mr. Scott, I give a brief account of the chief plankton phenomena in the Irish Sea during the past year. Both in connection with these plankton investigations and in Dr. Johnstone's observations on the distribution of plaice and other fish, we have a good deal of unpublished material which is still held up until times become more favourable for printing *in extenso.*

I desire in conclusion to record my gratitude to the successive Chairmen, Officials and Members of the Lancashire and Western Sea-Fisheries Committee for the opportunities they have given me for what I hope may be regarded as helpful co-operation during the last thirty years—since the days when my old friend Mr. John Fell, the first Chairman of the Committee invited me to attend an early meeting and give such advice as I could in regard to the scientific principles that form the basis of a rational sea-fisheries administration.

W. A. HERDMAN.

Oceanography Department,
University of Liverpool,
March 26*th*, 1920.

MID-WINTER INVASION OF NOCTILUCA AND CTENOPHORA.

By A. Scott, A.L.S

On Tuesday, December 16th, 1919, Barrow Channel was visited by an immense swarm of the Flagellate *Noctiluca* and the Ctenophores *Pleurobrachia* and *Beröe.* The invasion was sudden and short. Two days previously there was not the slightest indication that these plankton organisms were in the area. Two days later the many millions of *Noctiluca* and millions of *Pleurobrachia* had vanished and left no trace that anything unusual had occurred in the interval.

The routine duties of the laboratory usually require one or two visits to be made along the shore between tide marks each week for general information and collecting useful material. In the mussel fishing season the visits are more frequent. A certain amount of supervision is needed to see that the conditions of the concession for relaying mussels intended for food are observed. One of these duty visits was made on Sunday, December 14th, but nothing unusual was observed. Next day there was a remarkably heavy fall of rain which lasted for some hours. The rain was accompanied by a light southerly wind, but the sea was almost smooth. Another visit was made on December 16th, and attention was at once drawn to the presence of great numbers of ctenophora that had been stranded on the sandy mud flats during the ebb of the early morning tide. The area (500 yards wide and about 1,000 yards long) between Roa Island and Foulney appeared as if it had been thickly sprinkled with glass marbles. These were *Pleurobrachia.* The distribution was fairly uniform, but generally the numbers were distinctly greater on the slopes of the little gutters which cut through the flat muddy sand and act as drains. Mingled with the *Pleurobrachia* one

could detect flattened oblong jelly-like patches resting on the surface of the sand. A close examination showed that these were *Beröe* which, owing to their less rigid structure had just collapsed and fallen flat at the moment of stranding. Some had fallen on their sides and the result was an oblong patch of jelly. Others had stranded in an upright position and were left as rounded jelly spots. The *Beröe* seemed to disintegrate immediately the water left and it did not recover its shape on lifting it with a large spoon, taking the sand as well, and then slowly lowering the whole into a jar of sea water. Perfect specimens could only be obtained by collecting those still floating along with the *Pleurobrachia* in the little pools. On approaching the water's edge it was noticed that there was a well-marked brick-red oily looking zone all along the edge and extending outwards for a distance of six to twelve inches. The water in the creeks was completely covered with this thick oily layer. A sample was collected and the oily looking substance was found to be pure *Noctiluca.* Numerous specimens of *Pleurobrachia* and *Beröe* could also be seen floating about near the surface of the clearer water. A bucketful of *Noctiluca* was easily obtained and taken to the laboratory for further examination. A large number of *Pleurobrachia* were also collected for museum preparations and for use in the classes. The *Noctiluca* and *Pleurobrachia* were killed by adding strong formalin. Later on they were transferred to a two per cent. solution of the same reagent. Preserved in this manner the organisms retained their shape and characteristic appearance quite well. The *Noctiluca* remained fully inflated and the coarse flagellum was usually extended. The bucketful of living *Noctiluca* was transferred to a large wide glass cylinder and allowed to stand. In a short time the animals grouped themselves into a deep layer resting on a small quantity of sea water. This buoyant mass was just like thick tomato soup. Its volume was found to measure

fully 2,000 cubic centimetres. Some of the *Noctiluca* and *Pleurobrachia* were placed in a small tank of sea water, but without circulation. The *Pleurobrachia* died off after a couple of days. The *Noctiluca* lived and retained their phosphorescent character for three weeks. The organisms were examined for food contents. The *Noctiluca* were all quite empty and thus differed from those collected at Port Erin at the end of July which were completely filled with the diatom *Rhizosolenia stolterfothii.* With the exception of one *Pleurobrachia* all the ctenophora examined had no food in the stomodaeum. A perfect specimen of the amphipod *Calliopius læviusculus* (Kroyer) was found in the stomodaeum of one of the *Pleurobrachia.* This amphipod was recorded by A. O. Walker as long ago as 1889 from collections of plankton taken at low water at Puffin Island where it was very abundant. The species is widely distributed in the northern hemisphere, and is usually moderately abundant in shallow water among algae. The amphipod was quite fresh and evidently recently captured. On the 17th December—24 hours after these large collections were made—the whole area was again examined and only one *Pleurobrachia* was found. There was no *Noctiluca* in the plankton. The following day another investigation was made and nothing at all could be found of the *Noctiluca* and ctenophore invasion of the 16th December.

It is quite unusual to find an abundance of *Noctiluca* and ctenophora in our area in mid-winter. Immense visits of *Noctiluca* along the coasts of North Wales and Lancashire have been recorded by us at various times, but they have all been some time between the beginning of August and the end of September A few specimens may be present in some part of the Irish Sea at almost any time. *Noctiluca* was present in small numbers in the plankton collected at Port Erin in November and December, 1919. We do not know what the plankton between Lancashire and the Isle of Man was like

at the end of 1919, and cannot say that the *Noctiluca* occurring at Port Erin was part of the swarm that appeared on the North Lancashire coast in December. Ctenophora usually drift about at the surface of the sea in shoals of varying size, and are considered to be more abundant in May, June and July than at any other period of the year.* *Pleurobrachia* seems to be rarely completely absent from the plankton and small isolated examples are often met with. We have already recorded an extensive shoal visiting the North-West coast of Lancashire in mid June, 1913, which completely filled a tow-net in a few minutes, and numbers were stranded on the shores of Barrow Channel. *Pleurobrachia* occurred in most of the hauls taken at Port Erin in October and November, 1919. The greatest number captured at one time was 36. Esterly, in an interesting account of the "Ctenophora of the San Diego Region"† finds many more *Pleurobrachia* in August when the temperature and salinity of the water is highest than in any other month of the year. About 60 per cent. of the collections taken in August contain *Pleurobrachia*. One collection captured 3,300 specimens and another 1,000. The *Pleurobrachia* from the San Diego Region is considered to be a variety of the Atlantic *Pleurobrachia pileus*, and Esterly states that Bigelow found swarms of *Pleurobrachia* in the summer with the temperature at 14° and in January when the temperature was 7° in Massachusetts Bay. Steuer‡ records *Pleurobrachia* as being most abundant in the Adriatic from January to April, from 1900 to 1904. From 1898 to 1904 it was of irregular occurrence from June to October and was not taken at all in August. The literature on the subject seems to lead one to the conclusion that these invasions of ctenophora are quite

* 1906. Cambridge Natural History. Vol. I, p. 418.

† 1914. University of California Publications in Zoology. Vol. 13, No. 2, pp. 21-38.

‡ 1910. Planktonkunde (Leipzig und Berlin, B. G. Teubner).

spasmodic and may occur at any time no matter what the temperature of the water may be. One point that most writers are agreed upon is that during the summer months, and with high temperatures of the sea, the specimens captured are all small. In the winter months when the sea temperature is low the specimens are mostly of large size. That is very much what we find in the Irish Sea. The summer-caught *Pleurobrachia* rarely exceed 8 millimetres in height. Many of the specimens collected during the invasion in December were 22 millimetres high.

FOOD OF PORT ERIN MACKEREL IN 1919.

By A. Scott, A.L.S.

The mackerel fishery off Port Erin appeared to be much later in 1919 than in some previous years. It was not till the end of the first week of August that the fish were caught in any numbers. Professor Herdman, who was collecting plankton for the "Intensive Study" investigation, wrote me on August 8th as follows :—"Since the late phyto-plankton passed off the copepoda have been increasing, and on August 6th I got a rich copepod haul off Bradda Head and at once put out two mackerel lines and went back over the same ground, where a gannet was fishing. In a few minutes I caught fourteen mackerel. I opened them and took out the stomachs and found them crammed full of copepoda. I am sending a tube containing the contents of the stomachs of six mackerel. You might see how many species you can determine and how the results agree with the tow-net hauls."

The stomach contents were carefully washed out into a black photographic developing dish and examined with the pocket-lens to get a general idea of the constituents. Pieces of stomach wall were taken out and conspicuous organisms such as zoea and megalopa and the larger copepoda were counted individually and also removed. The residue was then well mixed with water, transferred to a measuring cylinder and allowed to stand till the volume became constant. It was read off and amounted to ten cubic centimetres. The organisms were afterwards estimated in the manner adopted in the examination of the plankton catches. The result is given in the first column below. The second column gives the mean number per fish of each organism in whole figures, with the exception of *Anomalocera*.

Megalopa	6	1
Zoea	59	10
"Mysis"	110	18
Podon	4	1
Calanus	30	5
Pseudocalanus	200	33
Temora	1,300	217
Centropages	12	2
Anomalocera	9	1·5
Acartia	310	52
Oithona	120	20
Oikopleura	4,300	717

Only perfect specimens of *Oikopleura* were counted. It is quite certain that the figures given do not nearly represent the true numbers eaten by the six fish. The stomach contents were very much digested, and it was quite obvious that the *Oikopleura* had suffered more in the process than the other organisms. The heads had become separated from the tails in very many cases. There were numerous muscle fibres present from the broken-down stomach walls which without careful examination, by staining, dehydrating and mounting could be easily mistaken for the tails of *Oikopleura.* Detached tails and heads were therefore not taken into account. The numbers given are an extremely low estimate of what were actually consumed.

On the same day the mackerel were caught Professor Herdman had taken five hauls with the coarse and fine nets in the same area where the fish were found. These enable us to compare the numbers of crustacea and *Oikopleura* in the plankton through which the fish were swimming with the actual contents of the stomachs. The total volume of the five hauls was 47 cubic centimetres. The mean number of copepoda present in each haul was practically 47,000 specimens, of which 34,000 were *Oithona.* Two species of copepoda present in the plankton hauls were not observed in the stomach contents.

The mean number of *Oikopleura* per haul was 1,000. The mean number of copepoda captured by each mackerel was 330. Two-thirds of this number consisted of *Temora*. The *Oikopleura* were greatly in excess of the copepoda and the mean number of the whole specimens was 717. Copepoda were much more abundant in the plankton catches than *Oikopleura*, whereas exactly the opposite was found to be the case in the stomach contents. This appears to be clearly not an instance of pelagic fish feeding upon the abundant organisms in its vicinity. During the mackerel fishery off Walney, in 1913, when ctenophora, chiefly *Pleurobrachia*, were extremely plentiful in the plankton we found that it formed practically the sole food of the fish for at least a couple of weeks.* It may be an example of selection on the part of the fish, as those gelatinous organisms may have a higher food value than we have been accustomed to think, but one can scarcely imagine the fish picking out the comparatively few *Oikopleura* from amongst the large numbers of copepoda round about it. *Temora* and *Pseudocalanus* were three and five times more numerous in the plankton than *Oikopleura*. The former was consumed at the rate of 1/14 of its numbers in the plankton, and the latter at the rate of 1/160. The *Oikopleura* was consumed at the rate of 2/3 its total in the plankton. It is possible that the mackerel caught on August 6th had passed through a plankton much richer in *Oikopleura* than was the case in the vicinity of Bradda Head. This is supported to some extent when the condition of the stomach contents is taken into account. Freshly eaten plankton organisms are quite well preserved if the fish have been feeding just previous to their capture. The semi-digested stomach contents of the mackerel caught on August 6th indicated that the food had been taken some time before.

The lateness in the appearance of mackerel off the S.W. of

* The Mackerel Fishery off Walney in 1913, Fish. Lab. Rept. for 1913, No. XXII, p. 19.

the Isle of Man was clearly not due to any scarcity of zoo-plankton organisms. On July 16th and 17th, when the phyto-plankton invasion was at its maximum and the hauls with the fine nets contained from 11 millions to 15 millions of *Rhizosolenia stolterfothii* alone, besides large numbers of other species, copepoda and *Oikopleura* were more abundant than on August 6th. The mean number of copepoda per haul on July 16th was 67,000 along with 5,000 *Oikopleura* and on the following day 108,000 copepoda and again 5,000 *Oikopleura*. On July 31st, when the invasion of phyto-plankton was obviously dying out, the mean number of copepoda per haul was 55,000 along with 1,000 *Oikopleura*. When the phyto-plankton was at its maximum it completely obscured the zoo-plankton organisms and a naked eye examination only of the collections gave the impression that copepoda, etc., were very scarce. It was only during the microscopic investigation of the hauls that the true proportions of phyto-plankton and zoo-plankton became known.

The following table gives the mean numbers per haul of zoo-plankton organisms present on the three dates in July and on August 6, which were represented in the mackerel stomachs of the latter date. The last column is the mean per fish for comparison with the mean per haul.

	July 16	July 17	July 31	Aug. 6	Aug. 6
Megalopa	1	2	0·5	3	1
Zoea	15	2	1	33	10
"Mysis"	13	3	0·5	5	18
Podon	0	5	75	96	1
Calanus	902	581	785	753	5
Pseudocalanus	13,000	10,275	2,515	5,468	33
Temora	9,800	5,150	2,470	3,012	217
Centropages	21	61	67	101	2
Anomalocera	32	0	0	4	1·5
Acartia	2,250	2,862	715	3,186	52
Oithona	40,825	89,340	48,387	33,930	20
Oikopleura	5,375	5,125	1,185	1,020	717

It is apparent from the above tables that the obvious abundance of the zoo-plankton organisms noted by Professor Herdman on August 6th was evidently not the entire cause of the sudden, although late, invasion of mackerel in 1919. The tables show quite clearly that the same zoo-plankton was far more abundant three weeks earlier when no fish were being caught. The presence of a very abundant phyto-plankton along with the zoo-plankton may have had some relation to the absence of the fish. There was a general scarcity of mackerel in the northern parts of the Irish Sea in 1919. The fishery off Walney was a complete failure, and phyto-plankton was abundant in Barrow Channel up to the first week of August. The fact that there was a sudden appearance of the fish just as the invasion of phyto-plankton died out, indicates that either the phyto-plankton itself or the causes which produced and prolonged the huge invasion of *Rhizosolenia*, etc., had a delaying influence on the approach of such pelagic fish as the mackerel to our inshore areas. The prolific mackerel fishery off Walney in 1913, lasted from the middle of June till the beginning of September. It occurred when there was a pure zoo-plankton which for a time consisted of ctenophora only.

ON THE DIETETIC VALUES OF HERRINGS AND OTHER FISHES.

By Jas. Johnstone, D.Sc.

The results of a few analyses which were made during 1919 as part of some advisory work carried on for the Cannery Committee of the Board of Agriculture and Fisheries may be recorded here.

Manx Summer Herrings.

As in previous years a good deal of attention was directed to this interesting fishery and samples of the herrings caught were received fortnightly from the Port Erin Biological Station. The first sample was taken about 23rd April, 1919, and the last one about 18th September. At the beginning of the season the fish were all immature, being in Hjort's Stage I; but by September 18th, about which time the fishery was discontinued, the herrings were spawning, and of the last sample of 12 fish four were spent. The maturation of the ovaries and testes was a fairly rapid process occurring mostly during August and September.

The methods of analysis were similar to those described in former reports. In all cases " proteid " is nitrogen $\times$ 6.25, and the apparently large errors of the analyses are traceable to the use of the particular factor 6.25, as may be seen by looking at the columns in the tables with the headings " *N*." These give the percentage of nitrogen in the dried extracted residues after deductions are made for the variable amount of " ash," which in the case of the canned products is mostly added salt. The samples taken for analysis were, in all cases, composite ones, small portions of the muscle substance from different parts of each of the fish in the sample being added together to form the material which was dried and extracted.

If we assume that the dried, extracted, ash-free muscle substance is " proteid " in some form or other—an assumption which is a fairly safe one to make—the figures in the column " *N* " give the percentages of nitrogen contained in these products. It will be seen that they are always less than 16, which is the percentage assumed when one multiplies nitrogen by 6.25 in order to obtain results expressible as protein. Generally speaking, as the percentage of fat increases so does the percentage of nitrogen in the dry, fat-free, ash-free residue diminish ; there are, of course, exceptions to this statement, but on the whole there is the relation suggested between the variation in fat and the quantity of nitrogen in the muscle substance.

The results of the analyses of Port Erin Herrings are given in the following table. Only the water in the muscle substance was found in the case of the sample of 25.4.1919. It was then assumed that water × oil $=80\%$ of the wet weight of the sample and that the percentage of ash was the same as in that of 14.5.1919. This gives us the results in brackets for the sample of 25.4.1919.

Manx Summer Herrings, 1919.

Date.	Water.	Oil.	Proteid.	Ash.	Total.	*N.*
25.4.19	78·3	(1·7)	(18·7)	(1·3)	(100·0)	—
14.5.19	75·8	3·7	18·8	1·3	99·6	15·6
29.5.19	69·9	8·6	19·5	1·3	99·3	15·4
12.6.19	63·6	17·4	17·1	1·1	99·2	15·0
9.7.19	58·8	22·4	17·1	1·0	99·3	15·2
31.7.19	56·1	23·8	16·4	·9	97·2	13·7
12.8.19	53·7	29·7	14·8	·8	99·0	15·0
3·9.19	55·1	29·4	13·8	·9	99·2	15·0
20.9.19	58·6	26·1	14·0	·9	99·6	15·5

The above results are also represented in the graph, Fig. 1, by smoothed curves. The actual percentages are plotted in the figure and it will be seen that the smoothing does

not take any liberties with the figures that cannot be justified by assuming the usual variability that occurs when one deals with organisms of any species. The percentage of oil rises from about 2% to a maximum of about 30% at the end of August and then begins to decrease. At the same time the percentage of water varies in a complementary fashion, falling from nearly 80% to a minimum which appears to occur just before the maximum of oil-contents occurs. Simultaneously with these changes the percentage of "proteid" falls, decreasing nearly steadily until the spawning occurs.

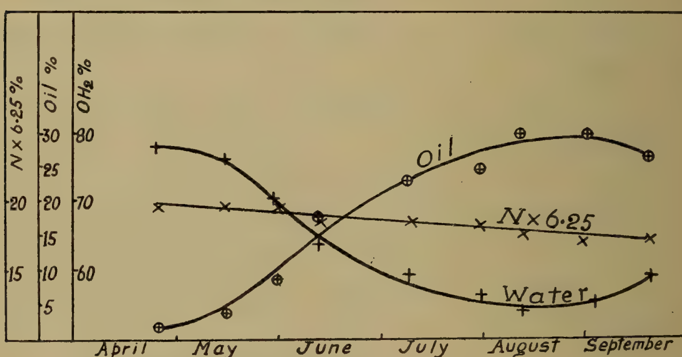


FIG. 1.

No samples were obtained after 20th September, the fishery being at an end by about that time and the herrings having left the locality of Port Erin. There is no doubt that had the shoals been sampled on their migration away from Isle of Man it would have been observed that the percentage of oil would have decreased to about 2%, that of water would have increased to 80%, and that of "proteid" would also have increased to its original percentage of about 19. That is, one would be justified in completing the curves so as to represent all the variabilities as cyclically repeated ones.

The variation of "proteid" however is not so simple a matter as the graph indicates. It is really nitrogen that is

estimated by the analyses, and one is not compelled to assume that the dry fat-free, ash-free, residue is proteid having a percentage of nitrogen = 16. As the analyses show this percentage varies between about 15.5 and 13.7%. The work done by Milroy* indicates that there are interchanges of substance between the flesh of the herring and the reproductive organs during the period of maturation of ova and spermatozoa. The proteids present in these tissues are certainly markedly different in composition, and it is also certain that, in each case, there are differences according to the stage of development of the gonads. What these differences are and what they mean have still to be made out. Neither must one assume that the "oil" in the flesh is always the same chemically, and here again precise investigation of seasonal changes would be very interesting.

On the whole these seasonal changes in the proportion of oil, water, and proteid, are repeated year after year in much the same way as Fig. 1 indicates. But there are quite marked (though minor) differences between one year and another, and Fig. 2 is meant to show this. The percentages of oil alone are

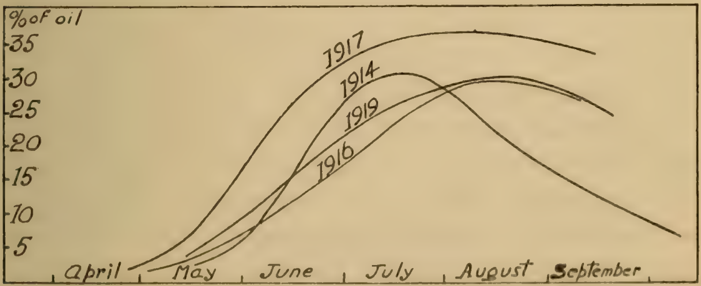


FIG. 2

* "Food value of the Herring," *24th Ann. Rept. Fishy. Bd. for Scotland*, Pt. III, pp. 83—107, 1906. *Ibid.* 25th Rept., pp. 197—208, 1908. "Changes in the chemical composition of the Herring during the Reproductive period," Biochemical Journal, Vol. III, pp. 367—390.

dealt with and the results are smoothed in much the same way as in the case of the data of Fig. 1. It will be seen that the curves are individual ones, the differences between one year and another being greater than any errors due to sampling that might reasonably be assumed. Generally, the percentage of oil increases to a maximum which occurs sometime just before spawning, that is about August or September, but the values may rise towards this maximum at different rates, as the graphs show, and there may be quite considerable differences in the time of occurrence of the maximum, as the curve for 1914 shows. It does not seem possible to account for these differences except on physical grounds, and it is very reasonable to suppose that they are due to accelerations or retardations of the process of fat formation by changes in the sea temperature. I have already* suggested how this temperature factor may operate, but no other data than those mentioned have since been obtained.

West Coast Mackerel.

A few samples of mackerel were obtained in 1919 and were examined in the same way as the Manx herrings. The season off the coasts of Lancashire and Wales is a variable one, beginning usually in June or July and ending in August or September. The migration appears to be one which is conditioned by the sea temperature, but it has not been investigated and little is known as to the spawning and feeding habits of the fish while in local waters. The mackerel is a highly suitable fish for canning, but so far it has not, or hardly at all, been utilised for this purpose in Great Britain. Obviously the very short season and the difficulty of obtaining regular supplies on a fairly large scale are great obstacles from the factory point of view, and these can only be overcome, it would appear, by recourse to the method of brine-freezing the fish as they can be obtained, and then by cold-storing until a sufficient quantity is obtained fully to employ a factory for some time.

* *Ann. Rept. Lancashire Sea-Fish. Laby. for* 1917, p. 56.

The analyses are given in the following table :—

Fresh Mackerel from Carnarvon Bay.

Date.	Water.	Oil.	Proteid.	Ash.	Total.	*N.*
7.7.19	70·8	8·6	19·7	·6	99·7	15·3
16.7.19	61·5	14·5	18·6	·9	95·5	12·9
30.7.19	69·9	7·1	19·1	·7	96·8	13·6
11.8.19	65·3	14·1	18·6	·6	98·6	15·1

The methods employed were similar to those used in the case of the Manx herrings, and the results are quite comparable. The sample of 30.7.19 consisted of rather small fish, and this accounts for the difference in fat-content between this sample and the adjacent ones. It will be seen that the percentage of nitrogen in the residue assumed to be "proteid" in nature is rather smaller than in the case of the herrings. Apart from this the analyses represent nothing calling for special remark.

Finnan Haddocks in Tins.

Through the kindness of the Norseland Canning Factory, Leeds, I was able to examine some samples of a very interesting cure: small haddocks which had been smoked in the usual way and then "processed" in hermetically-sealed tins similar to those in which herrings are put up. Three samples were examined by methods similar to those employed in the case of herrings, the first being analysed on 15.5.1919, shortly after the fish were packed, and two other tins being examined on 27.1.1920, after they had been stored for over six months. The results are as follows :—

Finnan Haddocks in Tins.

Date.	Water.	Oil.	Proteid.	Ash.	Total.	*N.*
15.5.19	71·53	·26	22·30	3·92	98·01	14·83
27.1.20	70·83	·18	21·06	3·94	96·01	14·56
27.1.20	69·84	·18	23·99	4·81	98·84	15·21

There is, of course, a considerable drying effect as the result of the smoking, and this accounts for the relatively small percentage of water and the large proportion of proteid. The haddock belongs to a group of lean fishes, and so the fat-content is very low—indeed, it may be neglected, since the results obtained, 0.18 to 0.26%, may be due to the presence of substances other than true fat which may be extracted from the flesh. The percentage of nitrogen in the residue assumed to be proteid is evidently low, but this, as we shall see, is due to the solution of nitrogenous substances from the flesh.

Each of the tins (which contained about ½-lb. of fish) also contained from about 25 to 50 c.c. of a turbid liquid. On filtering this, a clear, slightly yellow, glairy liquid was obtained, having a strong but very agreeable smell of finnan haddock. It was highly salt, uncoagulable by boiling and, during the few days that it was kept, showed no tendency to putrefy. Analysis showed that it contained a considerable quantity of proteid, thus :

Sample of 15.5.19	......0.5%	of nitrogen	= 3 %	"proteid"
,, ,, 27.1.20	......1.1%	,,	= 6.8%	,,
,, ,, 27.1.20	......1.2%	,,	= 7.6%	,,

The "proteid" was, however, probably largely gelatine altered by the sterilising process. Evidently the liquid in the tins, in this and other similar cures, is highly nutritious and ought to be eaten with the fish itself.

Titrated by Sörensen's method the liquid gave an appreciable reaction. A quantity of 5 c.c. required (15.5.17) 5.3 c.c. n/10 sodium hydrate solution for neutralisation to phenol phthalein, and the liquids from the matured samples required a little more, 6.1 to 6.4 c.c.

Maturation had occurred in the interval bewteen 15.5.19 and 27.1.20 in the sense that the bones of the fish had greatly softened. This is due, probably, to the acid reaction of the liquid contained in the tins.

Sprats.

Some samples of sprats, caught in the Moray Firth and being packed at the Norseland Factory, Leeds, were examined in November 1919. The fresh fish were about 11 to 13 cms. in length, very regular in size and fine-conditioned fish. The analytical results were

Water.	Oil.	Proteid.	Ash.	Total.	Nitrogen.
60.4	23.4	14.4	1.2	99.4	15.4

The same fish, packed in olive oil, and still unmatured, gave the results :

Water.	Oil.	Proteid.	Ash.	Total.	Nitrogen.
57.1	18.3	22.8	2.1	100.3	15.4

ON CERTAIN PARASITES, DISEASED AND ABNORMAL CONDITIONS OF FISHES.

By Jas. Johnstone, D.Sc.

1. Fungoid Infection of Plaice.

Parts of the organs of two plaice that had died in the Port Erin spawning pond were sent to me in September of 1916 by Mr. H. C. Chadwick. The liver, spleen, kidney, and the peritoneum covering the intestine of these fish contained small whitish nodules about one to two millimetres in longest diameter. Smaller cyst-like bodies were also seen in the substance of the liver. On dissecting out some of these larger nodules, staining and flattening out beneath a cover-glass it was seen that each was a fungus-colony, or growth. Fig. 2 represents a part of such a nodule as seen beneath a low power. It is a mycelium with sporangium-like bodies.

Fig. 1 represents part of a transverse section through a part of the intestine, and shows that the tissues of the latter are invaded by the fungus. The latter is represented in the figure by the black bodies. They are principally present in the submucosa, which is rather thicker than normally is the case, but some are also present in the tissue between the two layers of muscular tissue. Traces of mycelium are also to be seen in the section.

The affection, so far as the fungus is concerned, is similar, probably identical, with that described by me in 1905* in

* *Report Lancashire Sea-Fish. Lab.* for 1905, p. 179. Pl. XVI.

relation to plaice from the same source. As in the former case the liver was very extensively invaded by the fungus.

Obviously a mere examination of the morphology of the fungus as it occurs in these specimens is not sufficient for the identification of the species.

2. Tetrarhynchid larvae in the Plaice.

Tetrarhynchid larvae were fairly numerous in the plaice being adherent to the peritoneum over intestine and other viscera. Fig. 6 represents one of these larvae dissected out from its investments. It would be hazardous to attempt to identify its species. The form and attachment of the larva are similar in all respects to that given by me* in the general description of the larvae of *Tetrarhynchus erinaceus*. I have already found this species in the Plaice, and forms similar to that mentioned here.

3. Degenerate Cestode Larvae in Muscles of Hake.

In June of 1916 Dr. W. M. Tattersall, keeper of the Manchester Museum, sent to me a piece of a Hake " steak " that had been seized by a fish inspector in the public market. The flesh of the fish was greatly discoloured, black or dark grey in numerous patches, and on looking at these closely the discolouration was seen to be caused by very numerous, minute, black streaks among the muscle fibres.

Fig. 3 shows the appearance of the tissue when seen under a low magnification. The muscle fibres themselves are quite normal in structure, but lying among them are numbers of rod-like bodies, rather irregular in diameter, and usually with slightly swollen extremities. These are of very various length, perhaps from one quarter to one and a half millimetres. Some of them lie across the muscle fibres, but as a rule they

* " *Tetrarhynchus erinaceus*, van Beneden : Structure of larva and adult worm," *Parasitology*, Vol. IV, No. 4, pp. 1912, 371-2. Cambridge.

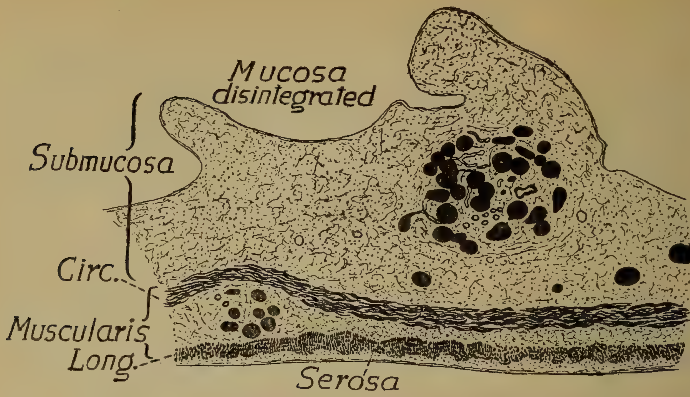


FIG. 1.

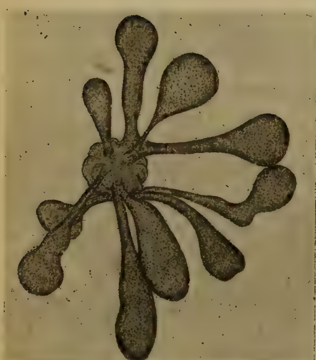


FIG. 2.

FIG. 3.

FIG. 4.

FIG. 6.

FIG. 1. Transverse section of the intestine of plaice infected with fungoid growths. Mag × 48 dia.
FIG. 2. A part of the fungus from a teased preparation of the liver of the same plaice. Mag. × 48 dia.
FIG. 3. Degenerate cestode larvae from muscles of hake. Mag. × 35 dia.
FIG. 4. The same in section. Mag. × 35 dia.
FIG. 6. Tetrarhynchid cyst from the peritoneum of the same plaice. Mag. × 110 dia.

are so placed that their longer diameters are parallel with those of the muscle fibres.

These bodies, Fig. 4, have a rather thick homogeneous investment of the nature of a cuticle, degenerated so that no traces of cellular or laminar structure is apparent. It stains readily, but even in the unstained condition it is dark brown or black in colour. Outside this there are shreds of tissue, the nature of which is doubtful. Within the investing, homogeneous layer, is a rod-like body, sometimes retracted away from the sheath. This is finely granular in structure, but with no traces of cells. Septa are quite absent so that the hypothesis of a hyphal nature for the bodies may be excluded. Also there is no branching.

Apparently these bodies are rather to be compared with a somewhat similar condition in the flesh of the Hake already described by me.* In this latter case the flesh contained minute round bodies with an obvious laminar structure. They were identified as degenerate eggs.

In the present case the most likely identification of the intrusive bodies is that they are degenerate Cestode larvae. It is true that there are no traces of hooks, or of the characteristic calcareous corpuscles, but the organism may be one in which there were no hooks on the scolex and the calcareous corpuscles may have completely degenerated or may have been dissolved by the process of preservation.

4. On the occurrence of a Birth-Pore in the Cestode *Anthobothrium musteli* (van Beneden).

A few cestodes obtained from the large intestine of the Ray (*Raia clavata*) and the Tope (*Galeus vulgaris*) were identified as van Beneden's species *Anthobothrium musteli*. Most of the specimens were immature strobilae, but several had

* *Report for* 1908 *of the Lancashire Sea-Fish. Lab.*, 1909, pp. 90-92. Pl.3, Figs. 2 and 3.

large, terminal proglottides, and on examining the latter with reflected light, under a low power, they seemed to have structures like the ventral suckers of trematodes. Not only had these structures raised elliptic rims, but they appeared to be subdivided by internal septa. Several of the ripe proglottides were stained and cleared and transverse sections were also made.

Fig. 7 represents, rather diagrammatically, a reconstruction made from one of these series of transverse sections. The sucker-like structure is shown by the elliptical outlines in the lower part of the figure. There are no very peculiar features in the anatomy of the reproductive organs. The genital pore is marginal. The cirrus is long and without spines or hooks. The vagina opens on the margin of the genital pit and the duct itself runs forward, curves round the greatly convoluted vas deferens and then runs backwards as an almost straight tube of variable calibre opening into the oviduct in the usual way. The vitelline glands are marginal and are greatly reduced at this stage of maturity of the proglottis. The testicular follicles are distributed over most of the segment except that part where the ovary occurs.

The uterine canal runs forward as a nearly straight tube of restricted calibre, and then suddenly swells out to form the uterus. Just at the latter place the widened-out uterus opens to the exterior by a pore placed on the anterior lip of the sucker-like structure. The arrangement is such as to suggest that the uterus itself must have been recurved backwards over the area represented by the raised sucker-like rim, and that its whole external wall over this part must have broken down. No stages intermediate between the condition represented in Fig. 7 and the immature stages generally found were, however, seen.

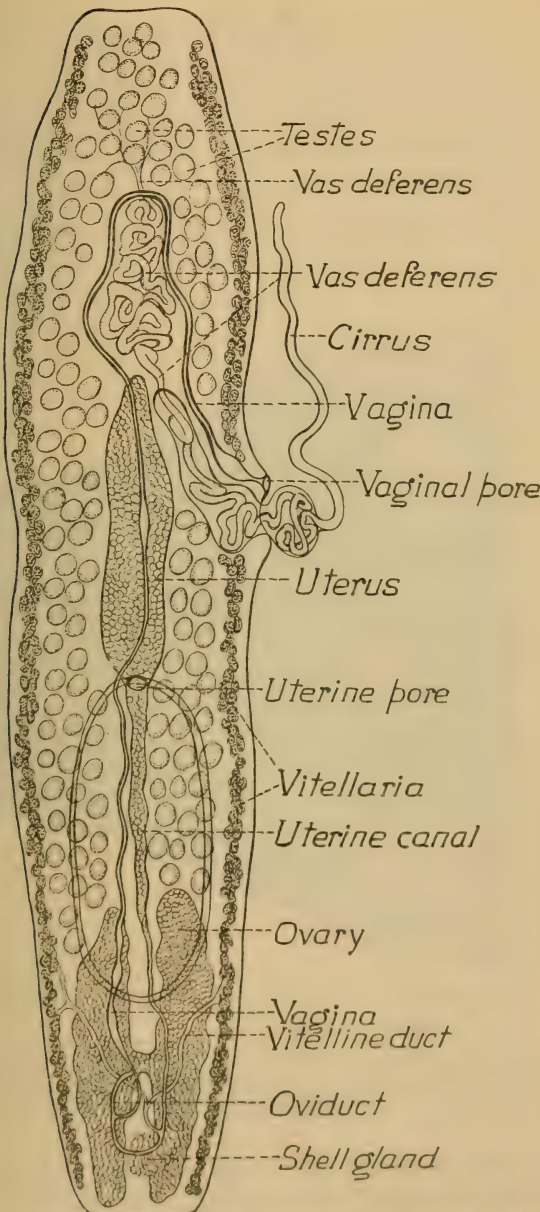


FIG. 7. A mature proglottis from *Anthobothrium musteli*. The drawing is diagrammatic and has been reconstructed from transverse sections.
Mag. × 30 dia.

5. Sarcomatous tumours in the mouth of a Cod.

A cod-head sent me by Mr. F. Stokes, fish inspector at Grimsby, had a number of tumours which were so noticeable as to suggest the condemnation of the fish. Fig. 8 represents, roughly, a dissection of this specimen, consisting mainly in opening from the side the cavity of the mouth and pharynx. There were several external tumours, one of which is shown projecting above the head: this growth had almost occluded

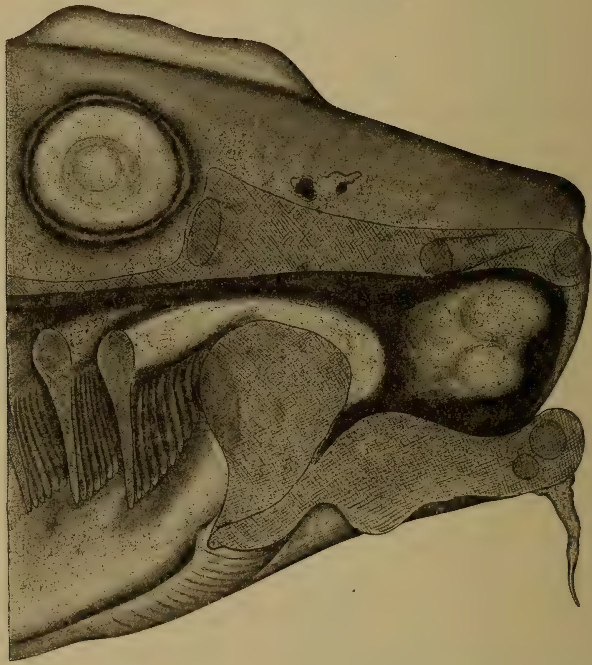


Fig. 8. Dissection of the head of a Cod to show sarcomatous tumours in the mouth. About half natural size.

the left orbit. Within the mouth were various large growths, and one of these is represented on the left internal wall of the cavity.

Sections were made through the various tumours. All of them are mixed-cell sarcomata, presenting no unusual features, so that it is unnecessary to reproduce the sections.

6. *Raia maculata* with additional pectoral fin.

A small Ray (*Raia maculata*) caught near Great Orme's Head, in the Irish Sea, was sent to me in January, 1917, by Mr. T. R. Bailey. The fish had a small, unpaired pectoral fin

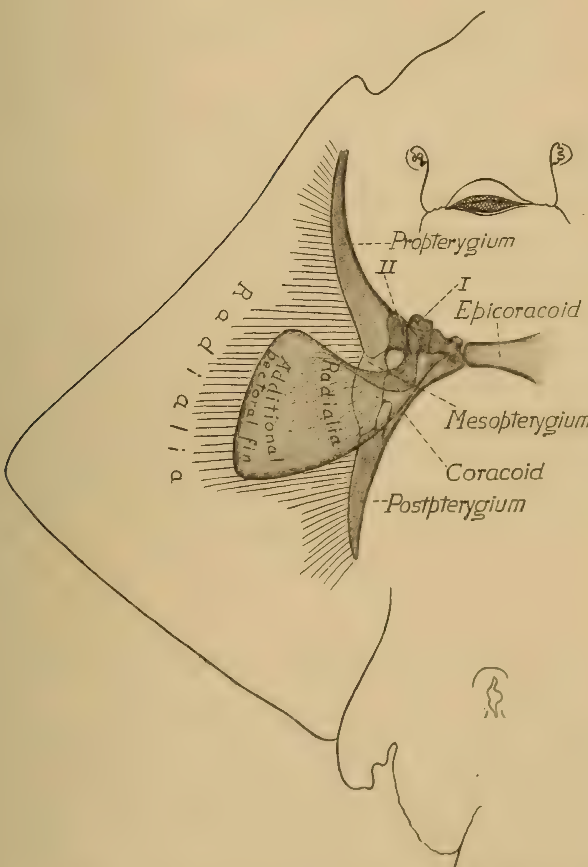


FIG. 9. Dissection of part of the shoulder girdle of a ray to show an abnormal extra fin skeleton. About half natural size.

projecting out from the right hand side of the pectoral girdle on the ventral surface. The fish was 24 cms. in breadth across the wings, and had a notch on the right pectoral fin near the

snout. This is not a very rare abnormality ; sometimes this notch is very deep, and sometimes it is paired, but more often it is unpaired. It indicates incomplete fusion of the pectoral fin with the anterior region of the trunk.

This interesting specimen is shown in Fig. 9. The ventral side is represented and the skeleton of the shoulder girdle and right pectoral fins is dissected out. The additional fin is shown : it is about 5 to 6 cms. in length, and in form very similar to the paired pectoral fin of a dog-fish. The coracoid is separated from the epicoracoid by an open suture without any ligament. The coracoid itself, and the pterygial skeletal elements are quite normal, except that there is a little lateral and ventral facet on the part where coracoid and epicoracoid meet. Articulating with this is a small roughly triangular cartilage (I in Fig. 9), and articulating with this again is a pterygial cartilage (II in Fig. 9). This extends along the anterior border of the additional fin, and to it are articulated a series of soft and very irregularly shaped radial elements. The remainder of the fin is soft and fleshy, very much resembling the adipose dorsal fin of Salmonoid fishes.

7. Sarcomatous tumours on the head of a Conger.

In 1916, Mr. T. A. Coward, of the Manchester Museum, sent me the head of a small Conger eel which had been seized and condemned in the local fish market. On the top and left side of the head was a large, hard tumour, nearly globular in shape and about 10 cms. in diameter. The Figures 10 and 11 represent the appearance of the head as seen from in front and from the left hand side.

The growth was firm and there was no necrosis in its interior parts. Over its surface the skin was rather darker than elsewhere, and there were irregular blotches of dark

pigment. In minute structure the tumour presented all the characters of a mixed cell sarcoma with much fibrous tissue. There was no indication of encapsulation.

FIG. 10. Front view of the head of a Conger, with a large sarcomatous tumour. About half natural size.

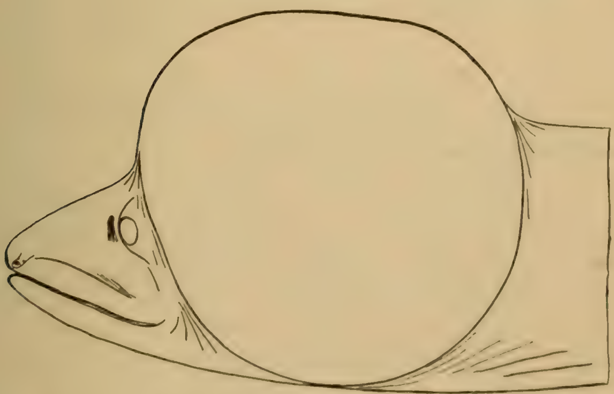


FIG. 11. Side view of the head of a Conger with a large sarcomatous tumour. About half natural size.

A CONTRIBUTION TO THE ECOLOGY OF SOME COCKLE BEDS.

By C. L. WALTON, M.Sc.
(Department of Zoology, University College of North Wales, Bangor).

The following notes are the result of observations made from time to time on various cockle beds on the west coast of England and Wales, between September, 1912 and September, 1919. The work has been much interrupted and is far from being complete, but it is hoped that the investigations may proceed further in due course. The present series of observations were gathered from Milford Haven to Morecambe Bay, during the progress of work under grants from the Board of Agriculture and Fisheries to Aberystwyth University in the first instance, and latterly from the Lancashire and Western Sea-Fisheries Laboratory, Liverpool University. All the beds mentioned (with the exception of Milford Haven) lie within the Lancashire and Western Sea-Fisheries area, while those most thoroughly examined are situated in the Dyfi Estuary.

I. Life Conditions as affecting the Fauna.

General situation of Cockle Beds.

The edible cockle (*C. edule*) and its accompanying fauna occurs in many places on the coast and under very varying conditions, but it cannot exist in large numbers unless the following conditions are fulfilled :—

1. An expanse of sand or sandy mud.

I have found cockles in almost pure mud and even in muddy gravel, in sufficient numbers to be picked for sale. In the former case they were well grown and numerous and

flourishing (Pwllcrochan, Milford Haven), but in the latter (Langum, Milford Haven) the shells were not numerous and were massive and coarse. As regards physical medium they occur most abundantly in estuarine sands in which a dark underlying layer of decaying organic matter occurs, though the largest shells have come from the purer sands of more marine conditions.

2. Current.

A moderate and constant flow seems essential, as upon this food supply, aeration and cleansing must to a great extent depend. Lack of flow must lead to stagnation and adverse conditions, while on the other hand too strong a current will lead to destruction through removal of the substratum or smothering of the cockle, etc., by deposition.

3. Stability.

A relative stability is therefore essential, and excessive current or wave action will be fatal. A study of maps or charts on which cockle beds are indicated will show that such shelter is supplied either by estuarine conditions or by protecting sand banks.

The conditions governing the Dyfi Estuary have been studied by several scientists, but the data given seldom relate to the actual area of the cockle beds. Geological and botanical information of great interest is given by R. H. Yapp, D. Johns and O. T. Jones, in "The Salt Marshes of the Dovey Estuary," *Journal of Ecology*, V, 1917. Vaughan Cornish, in "Waves of Sand and Snow," 1914, gives the results of a series of observations on the shifting sand areas of the Traeth Maelgwyn during May-June, 1900; while some winter salinities are given for the Dovey and Mawddach Estuaries by F. W. Durlacher, in connection with "Sewage Drift in Relation to Mussel Beds" (*Trans. Biolog. Soc.*, Liverpool, XXVIII, 1914). It is

obvious that wide fluctuations occur. The following temperaature readings were made on the Lavan Sands cockle beds (between Llanfairfechan and Aber) on September 9th, 1919 :—

A. Muddy patch with *Cardium*, etc. abundant, near shore. 2.20 p.m. Tide just receded; sun bright; strong N.W. breeze.

Air temperature	20° C. (just above surface).		
Sand ,,	1 inch below surface	(*Cardium* stratum)	19·40° C.
	2 inches ,,	,, ,,	18·60° C.
	3 inches ,,	(*Macoma* stratum)	17·00° C.
Water ,,	of stream draining bed, 3 inches deep		21·25° C.

B. On main cockle bed, almost pure sand; half-mile from shore. 3 p.m.

Air temperature	19·50° C.	
Sand ,,	1 inch below surface	20·00° C.
	2 inches ,,	18·50° C.
	3 inches ,,	16·80 C.

The beds at Ynyslâs (Dyfi Estuary) were examined during severe frost on February 12th, 1919, when the River Leri was frozen over at its mouth and the foreshore covered with 3 to 12 inches of ice. The cockles were unaffected, but all surface forms (*P. stagnalis*, *Littorina*, etc.) buried themselves and very few cases of *Arenicola* were noted. Scott* notes the effect of frost in Morecambe Bay resulting in great destruction of cockles and spawn. "The chief cause of the fluctuations of the fisheries for shell fish along the Lancashire coast is due to natural influence . . . the eggs produced by a spawning cockle are fewer in number than is the case with the mussel, and spawning takes place in the early spring. The spat from the bed of cockles may, therefore, be completely destroyed by the sea water becoming suddenly cooled as it flows over the surface of very cold sand." Kellogg† comes to similar conclusions regarding *Mya arenaria*, stating that a cold rain when the water is full of swimming larvae may have a disastrous effect, while several days of low temperature may cause it to be more widespread.

The adverse influence of wind was noted on September

* A. Scott, "Notes on the Flookburgh Cockle Bed," *Report Lancashire Sea-Fish. Lab.*, 1909.

† Kellogg, J. L., "Shell Fish Industries," 1910.

19th, 1918, while visiting the cockle beds on the Traethmawr (or Traeth Cocos) near Portmadoc. A violent N.W. wind dried the fine surface sand almost as soon as it was uncovered by the falling tide, causing it to drift shoreward in dense clouds. Many cockles became exposed, and soon gaped (owing to relaxation of the muscles), and fine dry sand entering caused their death.

On one area of muddy sand several acres in extent, and near the mouth of the River Clettwr (Dyfi Estuary), I noted in August, 1915, that only young cockles were present. About three inches below the surface there was a layer of dead shells of all sizes, in all probability the relic of a former bed destroyed by "sanding," and subsequently re-colonised.

II. Faunistic.

A mere list (even if annotated) of the animal forms constituting the fauna of cockle beds is of little value. Some attempt has, therefore, been made to regard the matter from the ecological standpoint, and some instances of succession of associations will be given, as illustrated by the Dyfi and Lavan Sands. In any locality studied variations may be expected, both as regards the composition of the associations and their extent. The cockle beds may be approached via sand dune, salt marsh, shingle bank or rocky reef, and in the Dyfi Estuary all these occur. Yapp, describes the tidal waters near Ynyslâs, as lined by salt marsh, the transitional zones between these and the moor behind being characterised by abundance of *Molinia*, *Juncus maritimus*, etc., etc., the succession shoreward being: (1) Juncetum maritimi, (2) Festucetum rubae, (3) Armerietum maritimae, (4) Glycerietum maritimae, and (5) Salicornetum europaeae, which make up the saltmarsh formation.

This belt bordering the typical marine zones is characterised by winding channels and innumerable "pans," whose history is traced in the paper above-mentioned. These "pans" contain a curious assemblage of insect larvae and marine animals, among those noted being *Sphaeroma*, *Gammarus*, small *Carcinus*, larval fish, young eels, *Paludestrina*, etc. The Salicornetum is an open association on bare silt and is often absent, the whole or part being occupied by sand dune, shingle, etc., with their respective faunas.

The Salicornetum is always, in my experience, too firm for *Cardium* and *Macoma*, and the fauna includes great numbers of the little *Paludestrina stagnalis* (*Hydrobia ulvae*), the burrowing crustacean *Corophium volutator* (*grossipes*), a few small *Arenicola*, *Nereis diversicolor* and a few *Littorina littorea*. This association passes into the more marine conditions of the cockle beds proper.

Petersen* in discussing the animal communities of the level bottom designates this zone the Macoma or Baltic Community, and states concerning it, "One community, the *Macoma*, seems to be altogether independent of the composition of the level bottom, living equally well on pure sand . . . . and on pure mud . . . . temperature and salinity are likely to be of importance." He ascribes the great abundance of bivalves in this zone to the absence of Echinoderms. "In the communities where *Amphiura* spread their arms abroad forming a network on the bottom, extremely few bivalves are found; the young being devoured. In the shallow coastal waters, etc., where Echinoderms are few or absent these young can persist, though the great majority never attain full growth and may be killed by wave action, etc. (probably the very factors that eliminate the Echinoderms). It is in such places that the Macoma communities can live and thrive continually,

* Petersen, C. G. J., "The Sea Bottom and its production of Fish Food," *Report Dan. Biol. Station*, 1918.

they are the only forms able to withstand the severe conditions prevailing, in a degree sufficient to ensure the maintenance of the species. It cannot be *depth* that keeps *Macoma* species out of the *Venus* area. *Mya arenaria*, *Macoma balthica*, *C. edule* and *Hydrobia* live in 20 m. in the Baltic, but in such places there are no Echinoderms."

Within the *Macoma* community in the beds examined, I find considerable variation in the distribution of the species inhabiting it. The chief of these are *Arenicola marina*, *Cardium edule*, *Macoma balthica*, *Tellina tenuis* and *Paludestrina stagnalis*, while, in addition, there are a number of others of lesser significance which will be mentioned later.

Macoma has a wider range than *Cardium*, occurring high in tides and in other places where *Cardium* is absent, and the same can be said for *Arenicola.*

We are also dealing with a *stratification* of species which explains some of the peculiarities of distribution: typically these strata are :—

1. The floating and swimming animals (Plankton) *Crangon*, *Mysis* and other Crustacea and fish and their larvae, that come and go with the tide; some, however, remaining in pools and streams left during low water.
2. Surface stratum, with *Paludestrina* dominant.
3. Stratum of *Cardium edule* one to one and half inches deep, short siphons protruded to the surface.
4. *Macoma balthica* (or *Tellina tenuis*) stratum, one and half to three inches below surface; siphons long.
5. Stratum of *Arenicola marina*, six inches to two feet below surface, burrows formed.

Cardium requires a moderately firm bed, especially in the more exposed situations, and further, the amount of organic matter present is, in my opinion, probably correlated with the relative abundance of the species. *Macoma* is less affected by surface conditions, and *Arenicola* considerably less.

Followed seaward *M. balthica* dies out and *Tellina tenuis* takes its place both in the Dyfi Estuary and on the Traeth Lavan, at about low water of ordinary spring tides, although I found them to overlap at about this level, below which *Tellina* also occurred in places apparently too unstable for *Cardium*; I can only agree with Woodward that the shell form of *Tellina* enables this species to survive where the heavier and thicker shelled form cannot adapt themselves.* Petersen† states that, " Transition stages between the successive communities are doubtless found as a rule in nature," but seem to occupy a very small part of the whole.

The following was the surface succession on a line taken across the Traeth Lavan, near Aber, on May 27th, 1919, roughly 1,000 yards and extending from the foreshore to the " commercial " cockle beds. Broadly, four faunistic zones were traversed :—

1. Steep, stony slope, 50 yards (more or less).
2. Muddy sand, level and wet, 150 yards.
3. Sand, fine, firm and less muddy and damp, 700-800 yards.
4. Coarse sand, a wide expanse.

Between 3 and 4 there was, in places, a shallow channel 50-100 yards wide.

1. Contains several sub-zones; in its upper drier portion were sand-hoppers; in the lower, *Fucus*, *Enteromorpha*; *Littorina littorea* (very abundant), *L. rudis*, *P. stagnalis* and *Carcinus*. *Littorina* may be considered the dominant form.

2. *Ulva*, *Ruppia maritima*; *L. littorea*, *L. rudis*, *Carcinus*, *P. stagnalis*, very common, and *Corophium voluator*. *Paludestrina* the dominant form.

3. *Paludestrina* (fairly common), *Arenicola* (common), *Macoma*, *Cardium*, etc.

4. *Cardium* (large), *Tellina tenuis*, *Arenicola*.

* See B. B. Woodward, *Proc. Malac. Soc.*, VII, 5, 1907 ; also Hunt, A. R. *Journ. Linn. Soc.*, XVIII, pp. 262-74.

† Op. cit., p. 13.

A similar traverse made near Llanfairfechan showed the following succession :—(1) Steep, stony shore. (2) Belt of soft dark mud with gravelly substratum : fauna rich in species and numbers. *Cardium*, *Macoma*, *Littorina*, *Paludestrina* (*Balanus* attached to some), *Arenicola*, *Terebella*, *Nereis* sp., and other Annelids and Nermertines, etc. *Carcinus*. (3) Channel of shelly sand, and *Terebella* the chief type. (4) Rippled sand 500 to 600 yards wide, a few *Arenicola*. (5) The cockle beds (as above) with *Tellina*.

The above examples, while illustrating succession, by no means indicate the number of animals present. With a view to gaining some information on this point, areas of one foot square were marked out on various parts of different cockle beds, and the numbers of the more abundant species enumerated as thoroughly as possible. A few examples will be given :—

A. Cope Scar, Priory Point, Ulverston. 6.8.1919. Sand firm and fine, with a black layer beneath. *Cardium*, 5 (and some minute young specimens) ; *Macoma*, 25 (average) ; *Paludestrina*, 30 to 50 ; *Arenicola*, 5 to 10.

B. Muddy zone, near Llanfairfechan, described above. 30.5.1919. *Cardium*, 14 ; *Macoma*, 62.

C. "Commercial" cockle bed on Traeth Lavan. 27.5.1919. *Cardium*, 1 to 3 ; *Arenicola*, 1 ; *Tellina* (variable but nowhere common).

D. Ynyslâs, near mouth of River Leri, Dyfi Estuary. 3.3.1919. Sand with dark underlayer. *Cardium*, 14 ; *Macoma*, 60 ; *Paludestrina*, 70 ; *Arenicola*, 5 (but very variable in the vicinity).

E. Same area. 25.7.1918. *Cardium*, 44 ; *Macoma* very numerous, but very young and fragile, and many broken in sifting the sand) ; *Paludestrina*, 300 ; *Arenicola*, 10.

An interesting feature at Ynyslâs is the penetration of *Macoma* and *Cardium* into the Salicornetum by means of streamlets or gutters which drain the area and run from one

to two (or more) feet below the level of the surface; their steep eroded clay banks are occupied by colonies of *Scrobicularea piperata.*

A factor that probably plays a part in causing unequal distribution of fauna is the set of currents and eddies affecting the floating larval stages (spat). Kellogg* gives good examples of this. He states that sometimes the set (of Lamellibranch spat) is quite evenly distributed, mostly it is irregular and thin but very dense in a few spots. These variations are due to sharply defined currents, or an eddy (or its margin) may sweep together astonishingly great accumulations. Two patches were studied, situated in a current and divided by a mat of eel grass, they were two or three yards wide and 200 yards long. In the middle of the spawning season they were as densely packed as it was possible for them to be, but before the end of the summer all died through overcrowding. In another spot, young clams settled 1,000 to 1,500 to the square foot, and from a similar area 1937 individuals about ½ inch in length were taken; while from another, where they had not completely buried 2,486 were sifted. In some areas various ages occur, which although crowded were not densely packed. There, therefore, appears to be a balance—the greatest possible number existing and attaining but slight growth.

In many cases the numbers of cockles present may have been affected by commercial gathering, but on the Dyfi beds this is of little account at present and, therefore, overcrowding is more likely to occur.

Arenicola must be of great ecological importance on the cockle beds, owing to its abundance and the work it performs. Ashworth† states that they are present in abundance where a rich diet of decomposing matter is available, and their absence or relative scarcity depends on two factors: (1) Purity

* Op. cit., pp. 307-8.

† Ashworth, J. H., "Catalogue of Chaetopoda of British Museum—Arenicolidae, 1912."

of sand, with consequent absence of food ; and (2) Force of sea and shifting character of sand. The number of castings per square yard at Musselburgh and Portobello are given at from 12-15 to 34-38, and at Barrow, 10-24 (average 20). Davidson* (quoted by Ashworth) estimated their numbers at Holy Island at 82,423 per acre, and the sand brought up yearly at 1,911 tons per acre, equalling a layer 13 inches deep. Thus in 22 months the whole sand, two feet deep, would pass through their alimentary canals. Their ova masses, anchored in the sand, are a feature of many cockle beds during the spring months.

Other worms found on the Ynyslâs beds include *Nereis diversicolor*, *Scoloplos armiger* and *Pygospio elegans*†.

Of Crustacea, *Corophium volutator* (*grossipes*) abounds on muddy areas near shore, and is seldom common on the cockle beds, where the sand is generally too fine for the formation of its burrows. *Neomysis vulgaris* and *Crangon vulgaris*‡ abound on the Dyfi beds, etc., in runlets of water. *Eurydice pulchra* is frequently met with swimming actively in shallow pools. Small specimens of *Carcinus maenas* are frequently met with, buried in the sand, all over the tidal region.

Mollusca—*Paludestrina stagnalis* is a most abundant form on those portions of the cockle beds nearest shore, and of a somewhat firm and muddy character ; it is scarce or absent on loose sands. Its egg masses were observed on May 26th, 1919, on the Traeth Lavan, exactly as described by Professor Herdman for Hilbre Island in June, 1888,§ and Lindstrom for Gotland (quoted by Herdman) ; these ova masses are placed upon the shells of the snails. I found 28 such masses upon a sample of 18 specimens collected at random—

* *Geol. Mag.*, 1891. Dec.

† I am indebted to Dr. E. J. Allen, F.R.S. for the identification of these.

‡ These species were kindly named by Dr. Calman, of the British Museum.

§ Fauna of Liverpool Bay, II, p. 8.

7	had no	adherent	ova	masses.
3	,,	1	,,	,,
4	,,	2	,,	,,
3	,,	3	,,	,,
1	,,	4	,,	,,

It was difficult to enumerate the number of ova per mass, on account of their dense coating of sand grains, and the tenacity with which they adhere to the gelatinous envelope. Twelve embryos were visible in one, but the full number is probably somewhat greater. Professor Herdman suggests that the species has acquired the habit of depositing ova upon its neighbours' shells as being the only comparatively stable basis available upon these sands.

This little species buries itself as soon as the sand or mud, upon which it usually crawls, commences to dry, and on sunny or windy days its presence can be detected only by the presence of numerous small holes. The same behaviour was noted during severe frost in February, 1919 (Ynyslâs) when not a single living specimen could be seen upon the surface.

Littorina littorea and *L. rudis* may be met with at times crawling on the firmer sands. These two species, and *Mytilus edulis*, manage to live on these otherwise unsuitable localities in a manner I have previously described.* Scattered over the surface of certain parts of the beds are clusters composed of one or more mussels fixed to either dead shells, or to one or more living cockles, which act as anchors. Upon the cockles, etc., may grow trailing tufts of *Enteromorpha*, and clinging to the mussels are generally several *L. littorea* and *L. rudis*. Within the mass and among the byssal threads are frequently to be found one or more specimens of *M. balthica*. Often a dozen individuals belonging to five species of Mollusca are involved in these clusters—in addition, the common *Balanus* may be attached also. The little *Tornatina* (*Utriculus*) *obtusa*

* *Journal Marine Biol. Assoc.*, X, 1. 1913.

(Montagu) is fairly common on the cockle beds in the Dyfi Estuary.

Cercariae of a number of species of parasitic Trematodes occur among the species enumerated, especially *C. edule*, *M. edulis*, *L. littorea*, *P. stagnalis* and *C. maenas*. The only species I have obtained is *Cercaria ubiquita* from *P. stagnalis*, at Ynyslâs, Aug. 25th, 1918. Miss Lebour gives the host as *C. maenas*.

Prof. Herdman* mentions having found many cockles infected with a minute Copepod, *Lichomolgus agilis*, which he regards as a commensal.

A complete list of all the species inhabiting a cockle bed would run to some length, including as it would many Foraminifera, Diatoms, etc.

The inter-relations of all these forms and their parasites form a most interesting cycle. As regards food Johnstone† states that the cockle feeds upon Algal spores, etc., etc., and this probably applies to all the bivalves mentioned. The food of *Arenicola* has already been mentioned. *Littorina* and *Paludestrina* are likewise vegetable feeders.

The Crustacea are generally carnivorous or omnivorous. Ehrenbaum‡ (quoted by Petersen and Jensen, 1911) states that larval forms contain Diatom skeletons and are probably detritus feeders, while adults either feed on mud from the bottom, or on worms, Amphipoda, Schizopoda, etc.

Herdman § considers that *Macoma* and *Cardium* are both of very great importance in furnishing food to the fry of flat fish at a time when they first become ground feeders, and leave off eating Copepoda. Adult flat fish (plaice, flounder, etc.) also feed largely upon the beds during high tide. The food of

* *Report Lancashire Sea-Fish. Lab.* 1892.

† *Report Lancashire Sea-Fish. Lab.*, 1899.

‡ Zur Naturgeschichte von *Crangon vulgaris*.

§ Op. cit. 1893.

the flounder consists principally of *Corophium*, according to Ashworth.*

Sea birds also take a heavy toll of the inhabitants, and Scott has some very interesting observations on this point.† " When we visited the Bardsea beds, our attention was drawn to a flock of gulls which were feeding on the adjacent sands, and to the excreta evacuated by them These consisted of well defined heaps of white, pale pink, and dark shells." The white were barnacles ; the pink " henpens " (Macoma) and the dark, comminuted mussels. All the heaps were practically pure, showing that the birds had confined themselves to one type of food at a time. Some mussels were nearly an inch long, and had been regurgitated ; the rest had gone through the intestine. It is considered doubtful whether undisturbed cockles are available to seagulls, and that gulls usually take the undersized ones left by gatherers. It is suggested, that owing to shortage of gatherers (due to the war) that the birds had taken to feeding on *M. balthica* and *Balanus*.

The effect of the many shore birds that feed within the tidal zone upon the surface forms of Invertebrates must be considerable.

* *Report Lancashire Sea-Fish. Lab.* 1899. p. 32.

† *Report Lancashire Sea-Fish.Lab.* 1915. pp. 61-2.

NOTES ON THE SHELL OF *CARDIUM EDULE.*

By C. L. Walton, M.Sc.

(Department of Zoology, University College of North Wales, Bangor).

Several writers refer to variability in the form of the shell in *Cardium*, and have made general statements referring to the relative thickness of shell, its obliquity, and other features to certain physical features of the environment.*

It is possible that a series of detailed measurements of samples from different beds would show these differences in a definite manner, and some preliminary work has been done.

One character that has attracted attention is the presence of certain prominent concentric grooves, the number of which has been generally taken to indicate the age of the shell, the grooves denoting periods during which growth has ceased, notably winter. An attempt has been made to test the validity of this belief. These "annual" grooves were found to be especially well marked in a sample recently collected on the Bardsea beds, near Ulverston (Morecambe Bay), in many cases the usually more or less well marked groove being replaced by a "step" separating the shell of one growth period from the next. These cockles occurred on a bank situated fairly high in tide marks, and therefore exposed to marked temperature range.

That these grooves do indicate age with some accuracy seems to me to be borne out by the table appended (Table I), since their number increases in a regular manner along with the increase in size of shell, throughout each given sample.

* Among these may be mentioned :—

Bateson, W., "On some variations of *C. edule* apparently correlated to the Conditions of Life." *Phil. Trans., Roy. Soc.*, London (B). Vol. 180. 1889.

Fullarton, J. H., 8th *Annual Report Fishery Board Scotland.* 1890.

Forbes, E. and Hanley, S., "History of British Mollusca," II. 1853.

Jeffreys, J. Gwyn, "British Conchology," II. 1863.

Table I.

Relation of Dorso-ventral diameter (depth) to growth lines, in 500 *C. edule.* 8.8.1919. Bardsea.

	Shell Groups.	No. of Shells.	Number of Grooves.				
			4	3	2	1	0
1	−1·00 cm.	1					1
2	1·00 to 1·50 cm.	80			1	16	63
3	1·50 to 2·00 cm.	194			2	70	122
4	2·00 to 2·50 cm.	102	2	4	43	42	11
5	2·50 to 3·00 cm.	119	6	56	54	3	
6	+3·00 cm.	4	1	3			
		500	9	63	100	131	197

Differences in their number and distinctness occur in different samples, owing to varying rates of growth, due to variations in food supply, such food supply being in my opinion connected with (1) the situation of the growing cockle within tidal range, (2) its situation with regard to currents, (3) the type of medium (mud, sand, etc.), (4) temperature, (5) spawning period (possibly).

The age grooves vary in number in my experience from one to eight; this latter in a "giant" shell from Solva in Pembrokeshire. The whole matter requires investigation, together with (1) the correlation of shell form (as indicated by series of measurements) with the environmental factors; (2) the similar correlation of density of the population of a given area with such features as the amount of organic matter present within the medium (soil) and a thorough examination of the life history, spawning periods, and development of the cockle. By such means also the reasons for the presence of local "giant" races of *C. dule* might become apparent. In addition to such beds of exceptionally large cockles as are usually mentioned (Barra),* etc., I have collected a sample

* Fullarton, J. H., 8*th Annual Report Fish. Board of Scotland* (for 1889). 1890. pp. 211-19. Map.

from Sandy Haven (Milford Haven) where a very limited bed exists, while another has been reported (and several examples sent to me) from Solva, also on the S. Pembrokeshire coast. In the case of Sandy Haven the largest example obtained measured 50 mm. in length, and the number of growth marks was seven. Two from Solva were both 55 mm. in length, and showed seven and eight grooves respectively. One Barra cockle I have seen showed no less than 10 !

The distribution of ages within a square foot of cockle bed is shown by the following examples, from Ynyslâs, Dyfi Estuary.

Table II.

		A.	*B.*
	Growth Lines.	No. of Cockles.	No. of Cockles.
1st year	0	2	6
2nd year	1	8	3
3rd year	2	9	17
4th year	3	8	13
5th year	4	4	5
		31	44

Ribs of Shell.

An examination of 400 shells (100 from Lavan Sands, nr. Bangor, N. Wales, and 300 from Bardsea, Morecambe Bay) shows distinctly that there is no correlation between the number of ribs present and age and size of shell. In the smallest cockles examined (group 0.98 to 1.50 cm. in dorso-ventral diameter) the number of ribs varied in exactly the same degree as in the largest (group 3.50 to 4.11 cm.).

The number of ribs ranged from 20 to 27 ; in other words, the number of ribs remains constant throughout life.

During the enumeration of the ribs, difficulty was encountered with regard to variability in the areas known as

L

the *lunule* and *escutcheon*,* especially the former. To be more exact, that part of the shell bordering the hinge line is very variable as to extent, ribbing, etc. Ribbing, at the lunule, may cease abruptly, leaving a space which is somewhat convex, and more or less obliquely verrucose, and which may be divided by one or more fissures which are due to the continuance of the growth lines; or this area may be obviously ribless, or resemble one broad flattened rib, or may be occupied by several obscure ribs. In quite a number of instances it is most difficult to decide as to the enumeration of the ribs in this portion of the shell, and an element of uncertainty is introduced.

TABLE III.

Number of ribs in 300 Bardsea cockles (total population of area examined). Length range 0·98 to 3·67 cm. 8.8.1919.

No. of ribs.	No. of cockles.
20	4
21	13
22	53
23	91
24	74
25	44
26	16
27	5
	Total ... 300

* Cooke, H. H., "Molluscs," Camb. Nat. Hist. 1895.

ON PERIODICITY IN THE ABUNDANCE OF PLAICE OFF THE MERSEY ESTUARY.

By R. J. Daniel, B.Sc.

In the report for 1917 of the Lancashire Sea Fisheries Laboratory (pp. 60-68) reference was made to a series of experimental hauls made by trawl nets having meshes of $\frac{1}{2}$ and $1\frac{1}{2}$ inch (measured from knot to knot). These experiments were made by the local fisheries officer, Mr. G. Eccles, a highly experienced fisherman, during the years 1892 to the present time. They are strictly comparable with each other, having all been made by the same person, and in the same way, and they form a very interesting series of data. In the present paper the results are considered more fully, and the years 1918 and 1919 are included.

Unfortunately, the records for the three years 1898–1900 for the fish trawl experiments have been lost; there is, however, no doubt as to the tendency of the data during the period in question.

Table I gives the actual data relating to the fish trawl experiments, every haul being recorded in the order in which it was made. The column "plaice per haul" gives the actual numbers caught during the time ("hours") stated in the adjoining column. Thus for the year 1892, 0 plaice were caught in a haul of 1 hour's duration, 88 in a haul of $\frac{3}{4}$ hour, 20 plaice in a haul of $\frac{3}{4}$ hour, and so on. At the foot of each column is given the total number of plaice caught in all the hauls made during the year, the total number of hours spent in making the hauls, and the average catch of plaice per hour's fishing.

Table II is arranged in a similar way, and gives the records for the experimental hauls made with the shrimp trawl, that is with the mesh of $\frac{1}{2}$ inch.

It will be seen that the total numbers of hauls made in each year vary greatly. For instance, 61 trials with a fish trawl were made in 1909, but only 16 in 1905. Further, the distribution of the trials throughout the various months of the year is not the same in every year. These irregularities lead to some degree of accidental variation, though they do not matter so much as might be supposed. The object of the "trials" was to "get fish," and so when the number of hauls is small, the plaice are not very abundant. Also the trials were generally made during the months when it was known that plaice were present, and these months are not always the same in different years. Generally then, the results represent the abundance of plaice in the locality, sampled better perhaps, than if they had been made rigidly according to a pre-determined routine.

Another irregularity is the variable duration of the hauls, but the time occupied in each does not differ very greatly from one hour. So although the "average catch per haul is not quite the same thing as the "average catch per hour," the difference is not great enough to confuse any conclusions based on the assumption that these averages are the same. The natural irregularities inseparable from the method of sampling are also a source of trouble, so that a graph of the average number of plaice caught per haul or hour's fishing, shows fluctuations which greatly exaggerate the variability from year to year.

Thus two or three exceptionally large hauls in one year raise the average, though inspection of the general run of the figures may show that quite mediocre results were the rule.

Therefore some method of expressing the general results, and at the same time minimising the importance of such exceptional hauls, must be adopted. This has been done, to some extent at least, by combining the results for each year with those of the one before and the one after; that is to say,

triennial averages are taken annually. Such three-yearly averages taken yearly remove the roughness of the graphs without affecting their general tendencies.

Tables III and IV, then, are prepared in this way. The averages of groups of three years are taken, thus: 1892–3–4, 1893–4–5, 1894–5–6, etc. The averages so found are plotted opposite the centre of the segments of the horizontal axis, representing the three-yearly periods; thus the triennial average for 1892–3–4 is placed above the centre of the length of the horizontal axis, representing the year 1893.

The data for the fish trawl catches for the years 1898–9 and 1900 are, as has been said, missing. To fill up this gap, as far as possible, two yearly averages have been calculated for the years 1896–7, and the result is plotted on the graph, Fig. 1, at the middle of the period 1896–7. Similarly the years 1901–2 have been taken, and their averages calculated, and the result is plotted against the middle point of the period 1901–2. The dotted straight line in the graph represents the results for the missing period of three years, and since it appears to occur on the descending limb of a curve, it probably indicates fairly what was the general tendency of the variations.

Tables III and IV give separate averages for the year 1918, and 1919, and the latter year is included by itself in the graphs for both fish trawl and shrimp trawl nets.

Now we assume that the results obtained in any one year may be influenced by the conditions of the year before and the year after, that is the rationale of taking triennial averages annually. But even then the graphs drawn from these values show irregularities and if there are one or two exceptionally large catches in any one year, the triennial average will be affected, though to a less extent than would annual averages. It will be seen that the maxima on the graphs include those years in which there are some exceptionally large catches, and conversely the minima are in periods when the catches are

small. This is to be expected, of course, but it should be noted that the greater the number of hauls in one period, the greater is what one may call the "chance" of getting an exceptional result—just by accident. Some method of finding an average which will not be unduly affected by one or two big hauls must, therefore, be found.

If we take three yearly groups thus, 1892–3–4, 1893–4–5, 1804–5–6, etc., and then tabulate the individual hauls in order of their magnitude, we obtain such a table as the following one :

1892-3-4. Fish Trawl.

No. of Plaice Caught per haul.	Frequency.	Summed Frequency.
0-50	13	37
51-100	6	24
101-150	1	18
151-200	2	17
201-250	3	15
251-300	2	12
301-350	3	10
351-400	2	7
401-450	2	5
451-500	1	3
501-550	1	2
551-600	0	1
601-650	1	1
	37	

That is, there were 37 hauls in all during the years 1892–93–94, and all of them caught either no plaice or some. There were 24 hauls in which either 51 or more than 51 were caught, 18 in which 101 or more than 101 were caught, and so on. These summed frequencies have been graphed by setting off the "numbers of plaice caught per haul" on the horizontal axis and the frequencies of occurrence of these catches on the vertical axis. As a rule, the points so found lie fairly regularly and a J-shaped curve (an exponential) is always obtained.

These curves have been drawn and smoothed by mechanical means. If one takes the middle point of the vertical axis (that would be 37/2 in the above series), draws a horizontal line to cut the curve, and then drops a perpendicular from the point of intersection to cut the horizontal axis, a point on the latter is found, which is the median.

In the example given the median is at 107 ; that is, in half of all the hauls less than 107 fish were caught in any one case, and either 107 or more than 107 in the other half of the hauls. Now, examine the way in which the horizontal axis is thus divided : half of all the hauls give a range of variation of catch which is from 0 to 107, and the other half gives a range which is from 107 to 650.

Now the smaller, in general, the catches are, the steeper will be the summational curve, and vice-versa. Therefore the range 0—median will be the shorter the smaller are the hauls, and will be the larger the bigger are the hauls This range 0—median may be called the " shortest half range," and obviously it is a measure of the dispersion.

It should be noticed that a slight change in the curvature of the graph, due to the smoothing, about the place opposite to the mid position on the vertical axis, shifts the position of the median. Such a variability of the constant must be taken into account as a statistical error, but even then the graph obtained by plotting the half-ranges (or the $\frac{2}{3}$ or $\frac{3}{4}$ ranges which can be obtained by the same general method) is a better representation of the change in abundance of the fish than are the annual average catches per haul or per hour's fishing, or the triennial averages taken annually. By this method a very big haul (which might raise the average to a great extent) becomes just what it is—one very exceptional result among a lot of ordinary ones.

The following table, then, gives the Shortest Half-Ranges obtained by the above method.

	1892 to 1894	1893 to 1895	1894 to 1896	1895 to 1897	1896 to 1898	1897 to 1899	1898 to 1900
6 in. trawl	0-107	0-275	0-310	0-357	—	—	—
½ in. ,,	0-159	0-105	0-217	0-137	0-200	0-83	0-60
	1899 to 1901	1900 to 1902	1901 to 1903	1902 to 1904	1903 to 1905	1904 to 1906	1905 to 1907
6 in. trawl	—	—	0-100	0-54	0-50	0-43	0-51
½ in. ,,	0-39	0-42	0-43	0-32	0-30	0-19	0-29
	1906 to 1908	1907 to 1909	1908 to 1910	1909 to 1911	1910 to 1912	1911 to 1913	1912 to 1914
6 in. trawl	0-70	0-125	0-140	0-212	0-157	0-147	0-78
½ in. ,,	0-75	0-142	0-157	0-165	0-94	0-95	0-59
	1913 to 1915	1914 to 1916	1915 to 1917	1916 to 1918	1917 to 1919	1919	
6 in. trawl	0-100	0-90	0-114	0-100	0-136	0-213	
½ in. ,,	0-75	0-50	0-43	0-36	0-110	0-139	

The following graphs represent these results. Fig. I is plotted from the triennial averages taken annually.

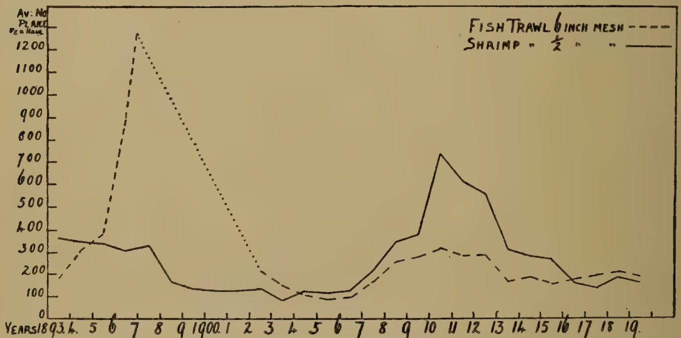


Fig. 1. Graph showing the numbers of plaice caught per haul. The points plotted are triennial averages taken annually.

Figure 2 represents the Shortest Half-Ranges.

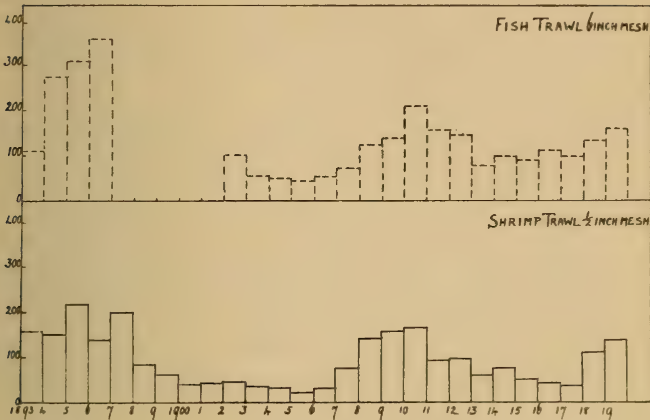


FIG. 2. Graph showing the variations in the abundance of plaice. The heights of the columns represent shortest half-ranges.

The two graphs show essentially the same conditions, but obviously Fig. 1 exaggerates the variability. We must conclude that the latter is real, that is, represents changes that actually occurred in the sea, because the general form of the graphs is the same, no matter how the figures are dealt with. The method of taking shortest half-ranges subdues the rather violent changes indicated by taking averages; thus the cusps are lower in Fig. 2. They are high in Fig. 1 because of the influence of the several exceptionally large hauls.

Taking the results of the catches made by the fish trawl net, we see that there must have been a minimum somewhere before 1892, and later minima about 1905 and 1915. There are maxima about 1896–8 and in 1910–11. The results of the fishing by the shrimp trawl show very much the same variations, but there are indications in Figs. 1 and 2 that the various maxima and minima occur earlier in the cases of the shrimp trawl catches than they do in the cases of the fish trawl ones. This is as one would expect, since on such grounds as those

inshore in Liverpool Bay the plaice population of the first two years of age is a relatively fixed one. Therefore the young fish of about 4–12 cms, such as are caught in the shrimp trawl, become the older fish of about 10–30 cms, which are caught in the fish trawl one or two years later.

Obviously the figures discussed here indicate that there is a periodicity in the abundance of plaice in the shallow water grounds of Liverpool Bay, and it is very likely that the same periodicity would have been observed in other inshore areas off the west coast, say in Morecambe Bay and the Solway. Since these shallow water areas are "nurseries," we should also expect that the same periodicity might have been traced in the catches of plaice made by the smacks and steam trawlers working on the deeper grounds offshore.

The observations made here have some relevancy in regard to the much-discussed question as to whether or not the restrictions on fishing for the period 1914-19 have led to an increase in the density of plaice on the fishing grounds. If the periodicity noted in Liverpool Bay holds for other grounds, it would not be sufficient to compare the pre-war and post-war years without taking it into account.

Table I. Mersey Estuary, 6 inch mesh.

	1892		1893		1894		1895		1896		1897	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	0	1·0	21	1.0	15	1.25	762	1·0	158	1·0	4492	1·0
	88	0·75	51	1.75	201	1.0	399	1·0	...	...	830	1·0
	20	0·75	10	0·75	258	0·5	400	0·75	...	...	2797	1·25
	9	0·75	0	0·5	61	0·75	263	0·75	...	...	67	1·25
	12	0·75	0	0·5	502	1·5	517	1·25	...	...	5	1·5
	322	2·0	13	0·5	66	1·0	322	1·0	...	...	560	1·0
	18	1·5	249	1·0	429	1·0	315	1·25	...	...	...	...
	290	2·0	489	1·5	92	1·25	348	1·0	...	...	...	...
	1	0·5	432	1·25	398	1·25	2082	1·25	...	...	...	...
	...	...	126	1·0	60	1·75	...	...	...	...	...	...
	...	...	636	1·5	342	1·0	...	...	...	...	...	...
	...	...	162	1·25	...	...	...	...	...	...	...	...
	...	...	159	1·75	...	...	...	...	...	...	...	...
	...	...	386	0·75	...	...	...	...	...	...	...	...
	...	...	342	1·5	...	...	...	...	...	...	...	...
	...	...	227	1·5	...	...	...	...	...	...	...	...
	...	...	8	1·5	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
Total	760	10·0	3311	19·5	2424	12·25	5408	9·25	158	1·0	8751	7·0
Average catch per hour	76		170		198		85		158		1250	

Table I. Mersey Estuary, 6 inch mesh—*continued.*

	1901		1902		1903		1904		1905		1906	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	14	1·5	6	1·5	40	1·5	31	1·0	63	1·0	12	1·25
	13	2·0	1017	1·0	65	1·25	13	1·0	3	1·5	19	2·75
	241	1·0	890	1·0	467	1·0	26	0·75	12	1·5	47	2·0
	144	1·0	70	1·25	325	1·5	23	0·75	48	1·0	40	1·0
	283	1·0	8	1·25	340	1·25	29	1·0	71	1·5	165	2·0
	92	1·5	553	1·25	241	2·0	0	1·0	192	1·0	28	2·0
	36	1·0	314	1·5	71	1·0	51	1·0	30	1·5	75	0·5
	308	1·5	166	1·0	41	1·0	8	1·0	11	1·5	64	2·0
	432	1·0	236	1·0	70	1·0	51	1·0	24	1·25	164	1·0
	...	...	13	1·0	93	1·25	2	1·0	73	1·5	8	2·0
	...	...	...	...	36	2·0	47	2·0	565	1·0	85	2·0
	...	...	...	...	105	2·0	13	1·5	43	1·25	83	2·0
	...	...	...	...	85	1·0	18	1·0	1	1·25	148	2·0
	...	...	...	...	486	1·0	54	1·0	71	1·25	35	2·0
	...	...	...	...	49	1·5	163	2·0	55	1·25	397	1·25
	...	...	...	...	247	1·0	105	2·0	110	2·0	46	1·0
	...	...	...	...	2	2·75	16	2,0	...	...	61	1·0
	...	...	...	...	...	...	14	1·5	...	...	120	1·0
	...	...	...	...	...	...	0	1·0	...	...	46	1·0
	...	...	...	...	...	...	62	1·5	...	...	362	1·0
	...	...	...	...	...	...	1	1·75	...	...	2	1·0
	...	...	...	...	...	...	15	2·0	...	...	443	1·25
	...	...	...	...	...	...	470	1·5	...	...	...	...
	...	...	...	...	...	...	399	1·0	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...
Total	1563	11·5	3273	11·75	2763	24·0	1611	31·25	1372	21·25	2450	33·0
Average catch per hour	136		279		115		52		65		74	

Table I. Mersey Estuary, 6 inch mesh—*continued.*

	1907		1908		1909				1910			
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	2	1·5	18	2·0	45	1·0	310	1·0	10	1·0	36	1·5
	1	2·0	3	1·5	624	1·0	1176	1·0	7	1·0	199	1·0
	10	2·0	17	1·5	412	1·0	27	2·0	6	1·0	73	1·0
	49	1·5	26	1·5	446	1·0	345	1·0	36	1·0	22	1·0
	81	1·0	56	0·5	94	0·5	58	1·0	9	1·0	125	1·5
	53	1·5	107	1·0	376	1·0	382	1·0	710	1·0	149	1·0
	108	1·0	286	1·5	72	1·0	13	0·5	308	1·5	175	1·5
	64	1·0	60	1·0	117	0·75	235	1·0	403	1·0	784	1·5
	22	2·5	12	2·0	269	1·0	842	1·0	142	1·0	216	1·0
	3	1·5	10	2·0	242	1·0	328	1·5	445	1·0	111	1·0
	7	1·5	0	1·0	1054	1·5	311	1·0	192	1·0	493	1·0
	597	1·25	822	0·75	344	1·0	226	1·0	193	1·0	244	1·5
	66	1·75	1677	0·75	546	1·0	544	1·0	75	1·0	225	1·0
	143	1·25	134	0·25	236	1·0	84	1·0	40	1·5	...	...
	42	1·0	302	1·5	132	1·0	123	1·0	220	1·0	...	...
	85	1·75	348	1·5	432	1·0	58	1·0	148	1·0	...	...
	43	1·0	408	1·0	921	1·75	2	2·0	881	1·25	...	...
	83	1·0	175	0·25	115	1·25	136	1·5	24	2·0	...	...
	109	1·0	338	1·0	122	1·5	107	1·0	157	1·5	...	...
	20	1·0	762	1·0	446	1·0	227	1·0	32	1·0	...	...
	19	1·0	507	1·0	678	1·0	92	1·25	233	1·5	...	...
	345	1·0	309	1·0	93	1·5	172	1·0	408	1·0	...	...
	0	2·0	444	1·5	121	1·5	267	1·5	149	1·0	...	...
	...	...	...	...	419	1·5	177	1·0	332	1·0	...	...
	...	...	...	...	41	1·0	47	1·5	886	1·5	...	...
	...	...	...	...	1176	2·0	...	...	570	1·5	...	...
	...	...	...	...	68	1·5	...	...	300	1·25	...	...
	...	...	...	...	88	1·0	...	...	509	1·0	...	...
	...	...	...	...	34	1·0	...	...	127	0·5	...	...
	...	...	...	...	80	1·0	...	...	326	1·0	...	...
	...	...	...	...	63	1·0	...	...	512	1·0	...	...
	...	...	...	...	238	1·0	...	...	122	1·0	...	...
	...	...	...	...	266	1·0	...	...	54	1·0	...	...
	...	...	...	...	1144	1·0	...	...	139	1·5	...	...
	...	...	...	...	472	1·0	...	...	288	1·0	...	...
	...	...	...	...	122	2·0	...	...	292	1·0	...	...
Total	1952	32·0	6821	27·0			18437	70·0			1213	56·0
Average catch per hour	61		253		263				217			

Table I. Mersey Estuary, 6 inch mesh—*continued.*

	1911				1912		1913		1914	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	198	1·0	123	2·0	52	1·5	216	1·0	0	1·0
	44	1·0	114	1·25	140	1·5	106	1·25	61	1·0
	0	2·0	157	1·0	94	1·5	68	0·75	61	1·0
	284	1·0	68	1·0	59	1·75	8	1·0	89	1·0
	72	1·5	353	2·0	76	2·0	106	1·0	24	1·0
	188	1·0	156	1·5	111	1·5	76	0·75	71	1·0
	786	1·0	319	1·5	952	1·0	67	1·0	67	1·5
	671	1·0	...	...	33	1·5	212	1·5	151	1·5
	633	1·0	...	...	54	1·5	187	1·0	47	1·0
	546	1·0	...	...	244	1·5	265	1·5	222	1·0
	119	1·0	...	...	153	1·0	113	1·5	76	1·25
	384	1·5	...	...	98	1·5	900	1·0	46	1·0
	676	1·0	...	...	52	1·0	793	1·0	23	1·5
	644	1·0	...	...	51	1·25	43	1·0	51	1·0
	1781	1·0	...	...	20	1·25	29	1·0	88	1·5
	847	1·5	...	...	33	2·25	860	1·5	126	1·0
	124	2·0	...	...	99	1·5	253	1·25	168	1·0
	499	1·5	...	...	362	1·5	152	1·5	53	1·0
	87	1·0	...	...	2	1·5	92	1·0	92	1·25
	543	1·0	...	...	0	0·5	32	1·0	49	1·0
	525	1·0	...	...	2	2·0	17	1·0	77	1·0
	837	1·25	...	...	0	2·0	93	1·0	51	1·0
	462	1·5	...	...	2	1·5	1550	1·75	101	1·0
	1411	1·5	...	...	...	...	447	1·5	59	0·5
	515	1·25	...	...	...	...	224	1·0	243	1·5
	313	1·0	...	...	...	...	109	1·0	220	1·0
	559	1·0	...	...	...	...	6	1·0	310	1·0
	359	1·75	...	...	...	...	160	1·0	49	1·0
	798	1·75	...	...	...	...	97	1·0	35	1·0
	16	1·5	...	...	...	...	4	1·5	146	1·0
	802	1·0	...	...	...	...	6	1·0	1386	1·0
	4	1·25	...	...	...	...	...	...	596	1·0
	232	1·5	...	...	...	...	...	...	21	1·0
	256	1·5	...	...	...	...	...	...	0	1·0
	59	1·0	...	...	...	...	...	...	...	...
	198	1·0	...	...	...	...	...	...	...	...
Totals			17772	55·0	2689	34·0	7291	35·25	4859	36·5
Average catch per hour	323				79		207		133	

Table I. Mersey Estuary, 6 inch mesh—*continued.*

1915				1916		1917		1918		1919	
Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
104	1·0	232	1·5	247	1·0	166	1·0	221	1·0	0	1·5
99	1·25	499	1·5	87	1·25	46	1·0	180	1·0	319	1·0
138	1·25	252	1·0	258	1·25	46	1·0	3	2·0	0	1·5
114	1·0	228	1·0	219	1·0	47	1·0	1162	0·75	315	1·0
49	1·0	377	1·0	191	1·0	40	1·5	5	1·5	194	1·0
163	1·0	295	1·5	8	1·0	274	1·0	494	0·75	256	1·0
171	1·25	24	1·5	26	1·0	23	1·25	5	1·75	59	1·25
204	1·25	192	1·5	31	3·0	378	1·5	231	1·0	251	1·0
197	1·25	377	1·0	9	1·0	14	1·5	39	0·75	85	1·5
87	0·5	...	...	82	1·0	44	1·0	4	1·0	358	1·75
13	1·0	...	...	54	1·0	6	1·0	215	0·75	154	1·0
81	1·5	...	...	8	1·5	22	1·0	4	1·0	49	1·0
53	1·0	...	...	16	1·5	2	1·0	273	1·0	207	1·0
135	1·5	...	...	217	2·0	51	0·5	33	1·0	251	1·0
518	2·0	...	...	101	1·0	29	1·0	41	1·0	316	1·5
81	2·0	...	...	230	1·0	21	1·0	68	1·0	227	1·0
96	1·5	...	...	71	1·5	143	1·0	71	1·0	...	...
12	1·5	...	...	64	1·5	220	1·5	32	1·0	...	...
53	1·25	...	...	...	...	283	1·0	113	1·25	...	...
71	1·5	...	...	...	...	50	1·0	58	1·0	...	...
124	1·25	...	...	...	...	331	1·25	55	1·0	...	...
353	1·5	...	...	...	...	380	1·0	113	1·25	...	...
32	1·25	...	...	...	...	280	1·0	195	1·5	...	...
52	1·25	...	...	...	...	720	1·25	32	1·0	...	...
50	1·5	...	...	...	...	259	0·75	1231	1·0	...	...
55	1·5	...	...	...	...	763	1·0	60	1·0	...	...
144	1·0	...	...	...	...	494	1·0	513	1·25	...	...
212	0·75	...	...	...	...	283	1·0	608	1·5	...	...
282	1·25	...	...	...	...	243	1·0	909	1·5	...	...
100	1·5	...	...	...	...	159	1·0	448	1·25	...	...
284	1·0	...	...	...	...	387	1·0	121	1·25	...	...
69	1·0	...	...	...	...	80	0·75	345	1·5	...	...
394	1·75	...	...	...	...	94	1·0	3	1·5	...	...
564	0·5	...	...	...	...	3	0·75	137	1·25	...	...
356	1·0	...	...	...	...	...	...	136	0·75	...	...
692	1·5	...	...	...	...	...	...	374	2·5	...	...
Totals		8578	56·5	1919	23·5	6381	35·5	8532	42·5	3041	19·0
Average catch per hour		152		82		180		201		160	

Table II. Mersey Estuary, ½ inch mesh.

	1892		1893				1894			
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	3	0·75	12	0·5	283	1·0	85	1·0	550	1·0
	30	1·0	49	0·75	225	1·0	407	1·25	857	1·0
	3	0·75	28	1·25	154	1·0	147	0·5	245	0·75
	0	1·5	140	1·0	98	1·0	656	1·0	144	1·0
	20	1·0	9	1·0	111	0·5	803	1·0	367	1·25
	30	1·0	47	1·0	379	1·0	414	1·0	72	1·0
	106	1·25	44	1·0	469	0·5	38	1·0	1029	1·0
	120	1·25	219	1·0	240	0·75	88	1·0	83	1·0
	106	1·25	111	1·25	920	1·0	441	1·5	343	1·0
	230	1·5	181	1·25	1620	1·25	647	1·25	61	1·5
	620	2·0	73	1·0	0	1·25	530	1·25	155	1·25
	60	1·25	13	1·0	0	1·5	284	1·5	1677	1·0
	110	1·25	23	1·0	179	1·0	150	1·0	52	0·75
	194	0·5	244	1·0	13	0·75	44	1·25	189	1·0
	444	1·25	10	0·5	1010	1·25	221	1·25	237	1·0
	495	0·5	16	1·25	10407	1·5	131	1·0	434	0·75
	2464	1·0	162	1·0	321	1·0	133	1·0	406	0·5
	1320	1·0	49	1·25	1567	1·25	522	1·0	258	1·0
	368	1·0	145	0·75	896	1·25	374	1·0	1600	1·0
	10	0·5	26	0·75	670	1·25	284	0·5	114	1·0
	108	1·25	207	1·25	895	1·0	164	1·25	11	1·0
	29	1·0	165	1·0	11	1·5	118	1·0	546	1·0
	28	1·0	26	0·75	323	0·75	364	1·0	20	0·75
	14	1·0	147	1·0	268	1·5	3	0·75	1147	1·5
	154	1·5	12	1·0	49	1·0	921	1·0	201	1·0
	...	...	65	1·0	15	1·25	127	1·0	809	1·5
	...	...	179	1·0	539	1·75	323	1·0	847	1·25
	...	...	5	0·75	138	1·5	402	1·0	...	...
	...	...	119	1·0	35	1·25	36	1·0	...	...
	...	...	63	0·75	304	1·0	212	0·75	...	...
	...	...	13	1·0	94	1·0	345	0·75	...	...
	...	...	114	1·5	68	1·0	261	1·0	...	...
	...	...	900	1·0	547	1·0	15	0·75	...	...
	...	...	0	1·5	332	1·0	234	1·0	...	...
	...	...	6	1·25	456	1·0	69	1·0	...	...
	...	...	303	1·25	256	1·0	601	1·0	...	...
Totals ...	7096	28·75			27817	76.0			23038	64·25
Average catch per hour	247		366				358			

Table II. Mersey Estuary, ½ inch mesh—*continued.*

	1895				1896		1897		1898	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	332	0·75	607	1·25	816	1·0	129	1·0	219	1·0
	6	1·0	668	1·0	1577	1·0	94	1·0	95	1·0
	0	0·5	918	1·5	365	1·0	158	1·0	810	0·75
	25	1·0	284	1·5	291	1·0	63	0·5	123	0·75
	15	0·5	617	1·0	465	0·75	127	1·25	818	1·25
	3	1·0	62	1·0	489	1·0	1278	1·0	113	1·25
	3	0·75	487	1·25	279	1·0	378	1·0	55	0·75
	59	1·0	...	...	979	1·0	307	1·0	15	1·0
	49	1·0	...	...	239	1·0	111	1·0	96	1·0
	118	1·0	...	...	410	1·25	...	...	18	1·0
	7	1·0	...	...	189	1·5	...	...	113	1·0
	118	1·0	...	...	229	1·0	...	...	243	1·0
	124	1·5	...	...	6	1·25	...	...	74	1·0
	117	1·0	...	...	478	1·0	...	...	287	1·25
	20	1·5	...	...	536	1·0	...	...	79	1·0
	19	1·0	...	...	25	1·0	...	...	540	0·75
	0	1·25	...	...	110	1·0	...	...	85	1·0
	2	1·25	...	...	997	1·25	...	...	326	1·0
	42	1·5	...	...	...	...	...	...	75	1·0
	35	1·25	...	...	...	...	...	...	193	1·25
	119	1·25	...	...	...	...	...	...	174	1·0
	75	1·25	...	...	...	...	...	...	...	...
	581	1·0	...	...	...	...	...	...	...	...
	39	1·0	...	...	...	...	...	...	...	...
	93	1·0	...	...	...	...	...	...	...	...
	39	1·0	...	...	...	...	...	...	...	...
	199	0·75	...	...	...	...	...	...	...	...
	145	1·25	...	...	...	...	...	...	...	...
	433	0·5	...	...	...	...	...	...	...	...
	309	1·0	...	...	...	...	...	...	...	...
	240	1·25	...	...	...	...	...	...	...	...
	166	1·25	...	...	...	...	...	...	...	...
	2315	1·0	...	...	...	...	...	...	...	...
	52	1·5	...	...	...	...	...	...	...	...
	472	1·0	...	...	...	...	...	...	...	...
	53	1·5	...	...	...	...	...	...	...	...
Totals			10067	46.75	8480	19·0	2645	8·75	4551	21·0
Average catch per hour			215		446		302		217	

M

Table II. Mersey Estuary, ½ inch mesh—*continued.*

	1899		1900		1901		1902		1903	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	15	1·0	81	1·0	6	1·0	63	1·25	22	1·0
	31	1·0	17	1·25	1	1·25	181	1·25	95	1·0
	62	1·0	2	1·0	24	1·0	2	0·75	38	1·0
	16	1·25	29	1·0	17	1·75	46	1·5	27	1·0
	11	1·0	2	1·0	1	1·0	41	1·0	16	1·0
	7	1·25	98	1·0	256	1·0	95	1·5	66	1·25
	3	1·25	34	0·75	21	1·25	69	1·5	85	1·25
	35	1·25	18	1·0	0	1·0	264	1·25	64	1·25
	7	0·75	265	1·25	49	1·0	339	1·5	2	1·25
	92	0·75	44	0·5	34	1·0	18	1·5	9	1·0
	265	1·0	99	1·0	36	1·0	2	1·25	9	1·0
	7	1·25	25	1·0	193	1·25	72	1·0	11	1·0
	104	1·0	158	1·25	1167	1·0	22	1·25	119	1·25
	699	1·25	...	...	645	1·25	44	1·0	21	1·0
	950	1·25	...	...	291	1·0	130	1·25	683	1·25
	83	1·5	...	...	20	1·0	23	1·25	...	...
	50	1·25	...	...	110	1·0	148	1·25	...	...
	20	1·5	...	...	174	1·25	7	1·0	...	...
	117	1·5	...	...	83	1·5	28	1·25	...	...
	12	1·25	...	...	791	1·0	427	1·25	...	...
	0	0·5	...	...	...	...	...	...	...	...
	20	1·25	...	...	...	...	...	...	...	...
	70	1·0	...	...	...	...	...	...	...	...
	120	1·0	...	...	...	...	...	...	...	...
	74	1·25	...	...	...	...	...	...	...	...
	5	1·5	...	...	...	...	...	...	...	...
	28	1·25	...	...	...	...	...	...	...	...
	54	1·0	...	...	...	...	...	...	...	...
	43	1·25	...	...	...	...	...	...	...	...
	113	1·5	...	...	...	...	...	...	...	...
	5	1·0	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
Totals ...	3118	35·75	872	13·0	3919	22·5	2021	24·75	1267	16·5
Average catch per hour	87		67		174		82		77	

Table II. Mersey Estuary, ½ inch mesh—*continued.*

	1904		1905		1906		1907		1908	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	23	1·0	2807	1·0	15	1·5	72	1·0	748	1·25
	10	1·75	39	1·0	26	1·25	11	1·0	133	1·5
	12	1·0	35	1·5	39	1·5	136	1·25	168	1·0
	7	1·75	47	1·25	11	1·5	20	1·0	175	1·25
	10	1·0	50	1·0	212	1·25	6	1·0	85	1·5
	2	1·0	58	1·5	23	1·0	30	1·0	218	1·0
	17	1·0	7	1·0	339	1·25	3	1·0	155	1·0
	1	1·0	415	1·5	84	1·25	105	1·25	445	1·5
	18	1·0	25	1·25	0	1·0	0	1·0	578	1·5
	11	1·25	145	1·25	4	1·0	7	1·0	119	1·0
	41	1·25	25	1·25	68	1·0	134	1·0	386	1·0
	15	1·0	26	1·5	258	1·0	332	1·0	113	1·0
	633	1·25	77	1·0	4	0·75	4	1·0	63	1·0
	41	0·75	183	1·5	53	1·0	225	1·0	547	1·0
	311	0·75	24	1·0	39	1·0	2	1·0	5	1·0
	22	1·0	9	1·25	46	1·0	619	1·25	1540	1·0
	117	0·75	26	1·0	5	1·0	179	1·0	180	1·0
	45	0·75	99	1·0	138	1·5	3	1·0	19	1·5
	34	1·0	26	1·0	101	1·0	12	1·0	2649	0·75
	54	1·0	69	1·25	5	0·75	3	1·0	200	1·0
	4	1·0	...	...	45	1·0	5	1·0	208	0·5
	...	...	...	...	13	1·0	340	1·0	354	1·0
	...	...	...	...	8	0·75	120	1·5	2300	1·5
	...	...	...	...	9	1·0	...	...	104	1·0
	...	...	...	...	43	1·0	...	...	294	1·0
	...	...	...	...	256	1·0	...	...	17	1·0
	...	...	...	...	599	1·0	...	...	134	0·5
	...	...	...	...	5	1·0	...	...	657	1·25
	...	...	...	...	...	...	...	...	71	0·5
	...	...	...	...	...	...	...	...	22	0·75
	...	...	...	...	...	...	...	...	6	1·0
	...	...	...	...	...	...	...	...	298	1·0
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
Totals ...	1418	22·25	4192	24·0	2448	30·25	2368	24·25	12991	33·75
Average catch per hour	64		175		81		98		385	

Table II. Mersey Estuary, ½ inch mesh—*continued.*

	1909		1910		1911		1912		1913	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	1090	0·5	505	1·0	760	1·0	1654	1·0	214	1·0
	1185	1·0	147	1·0	122	1·0	1556	1·0	0	1·0
	168	1·0	425	1 0	562	1·5	822	1·0	61	0·75
	1639	1·0	411	1·5	1724	0·75	694	0·75	602	1·0
	74	0·75	65	1·0	93	1·0	192	1·0	90	1·0
	155	0·75	103	1·0	562	1·0	0	1·25	58	1·0
	1301	1·5	14	0·75	522	1·0	2	0·75	29	0·5
	156	1·5	140	1·0	91	1·0	1466	1·0	472	1·0
	673	1·75	91	1·0	39	1·0	2364	1·0	680	1·0
	92	1·0	54	1·0	640	1·25	54	0·75	296	1·0
	86	1·0	13	1·0	5	1·0	4	1·0	1008	1·0
	0	1·0	0	1·5	0	1·0	12	1·0	157	1·0
	0	1·0	4	1·0	13	1·0	3	1·0	23	1·0
	13	1·25	66	1·0	360	1·0	5	2·0	505	1·0
	374	1·25	420	1·5	16	1·0	1	1·5	616	1·0
	63	1·0	410	1·0	1403	1·5	0	1·5	89	1·0
	1627	1·25	7	1·0	14697	1·5	1	1·0	3	1·0
	843	1·0	...	...	1328	1·0	0	1·5	93	1·0
	...	...	...	...	2328	1·5	1	1·0	27	1·0
	...	...	...	...	433	1·0	0	1·0	62	1·0
	...	...	...	...	806	1·5	5	1·0	7	1·0
	...	...	...	...	0	1·0	4	1·0	121	1·0
	...	...	...	...	4018	1·0	321	1·0	14	1·0
	...	...	...	...	...	...	3	1·5	106	1·0
	...	...	...	...	...	...	7	1·5	2	1·25
	...	...	...	...	...	...	202	1·0	139	1·0
	...	...	...	...	...	...	969	1·5	431	1·0
	...	...	...	...	...	...	804	1·5	54	1·0
	...	...	...	...	...	...	0	1·0	43	1·25
	...	...	...	...	...	...	15	1·5	121	1·5
	...	...	...	...	...	...	386	1·0	122	1·25
	...	...	...	...	...	...	271	1·0	...	...
	...	...	...	...	...	...	0	1·0	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...
Totals ...	9539	19·5	2875	18·35	30522	25·5	11818	37·5	6245	31·5
Average catch per hour	489		157		1197		315		198	

Table II. Mersey Estuary, ½ inch mesh—*continued.*

	1914		1915		1916		1917		1918		1919	
	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours	Plaice per haul.	hours
	1672	0·75	621	1·5	0	1·0	10	1·0	611	1·0	143	0·75
	79	0·5	919	1·5	146	1·5	7	1·0	55	1·5	351	1·0
	98	1·0	44	1·0	203	1·0	1	1·5	1175	1·0	130	0·5
	48	0·5	796	1·0	148	1·0	68	1·25	138	1·5	240	1·0
	34	1·0	55	1·0	0	1·0	963	1·0	35	0·5	210	1·0
	95	1·25	294	1·0	9	1·0	34	1·0	0	1·25	385	1·0
	29	1·0	105	1·0	7	1·0	...	...	117	0·75	35	1·0
	4	1·75	322	1·5	1	1·0	...	...	106	0·75	143	1·0
	93	1·0	17	0·5	4	1·5	...	...	12	1·0	0	1·0
	345	1·0	126	1·0	10	1·25	...	...	104	1·25	3	0·5
	7	1·0	4	1·5	0	1·25	...	...	4	1·0	146	1·0
	11	1·0	0	1·25	0	1·0	...	...	...	...	204	1·0
	2	1·0	1	1·0	23	1·0	...	...	...	...	...	...
	1401	1·0	4	1·5	101	1·5	...	...	...	...	...	...
	15	1·0	217	1·0	242	1·0	...	...	...	...	...	...
	1356	1·0	427	1·5	255	0·75	...	...	...	...	...	...
	6	1·5	...	...	...	...	...	...	...	...	...	...
	2709	1·0	...	...	...	...	...	...	...	...	...	...
	2	1·5	...	...	...	...	...	...	...	...	...	...
	84	1·0	...	...	...	...	...	...	...	...	...	...
	91	1·0	...	...	...	...	...	...	...	...	...	...
	648	1·0	...	...	...	...	...	...	...	...	...	...
	2152	1·0	...	...	...	...	...	...	...	...	...	...
	3	1·0	...	...	...	...	...	...	...	...	...	...
	0	1·0	...	...	...	...	...	...	...	...	...	...
	0	1·25	...	...	...	...	...	...	...	...	...	...
	1	1·5	...	...	...	...	...	...	...	...	...	...
	5	1·5	...	...	...	...	...	...	...	...	...	...
	1	1·5	...	...	...	...	...	...	...	...	...	...
	79	1·5	...	...	...	...	...	...	...	...	...	...
	20	1·25	...	...	...	...	...	...	...	...	...	...
	1272	0·5	...	...	...	...	...	...	...	...	...	...
	447	1·0	...	...	...	...	...	...	...	...	...	...
	121	1·0	...	...	...	...	...	...	...	...	...	...
	46	1·0	...	...	...	...	...	...	...	...	...	...
	124	1·0	...	...	...	...	...	...	...	...	...	...
Totals	13100	38·7	3952	18·75	1149	17·85	1083	6·75	2357	11·5	1990	10·75
Average catch per hour	336		211		64		160		205		185	

Table III. Three Yearly Periods.

Average catch of Plaice per haul, 6 inch mesh.

	1892-94	1893-95	1894-96	1895-97	1896-97	1901-03
Total Plaice per period	6495	11143	7990	14317	8909	7599
No. of hauls ,, ,,	37	37	21	16	7	36
Av. plaice per haul ...	175	301	380	895	1273	211
	1902-04	1903-05	1904-06	1905-07	1906-08	1907-09
Total Plaice per period	7647	5746	5433	5774	11223	27210
No. of hauls ,, ,,	51	57	62	61	68	107
Av. Plaice per haul ...	150	101	88	95	165	254
	1908-10	1909-11	1910-12	1911-13	1912-14	1913-15
Total Plaice per period	37395	48346	32598	27752	14839	20728
No. of hauls ,, ,,	133	153	115	97	88	110
Av. Plaice per haul ...	281	316	283	286	169	188
	1914-16	1915-17	1916-18	1917-19	1918	1919
Total Plaice per period	15356	16878	16832	17954	8532	3041
No. of hauls ,, ,,	97	97	88	86	36	16
Av. Plaice per haul ...	158	174	191	209	237	190

Table IV. Three Yearly Periods.

Average catch of Plaice per haul, ½ inch mesh.

	1892-94	1893-95	1894-96	1895-97	1896-98	1897-99
Total Plaice per period	57951	60922	41585	21192	15676	10314
No. of hauls ,, ,,	161	178	124	70	48	61
Av Plaice per haul ...	360	342	335	303	327	169
	'98-1900	'99-1901	1900-02	1901-03	1902-04	1903-05
Total Plaice per period	8541	7909	6812	7207	4706	6877
No. of hauls ,, ,,	65	64	53	55	56	56
Av. Plaice per haul ...	131	124	128	131	82	123
	1904-06	1905-07	1906-08	1907-09	1908-10	1909-11
Total Plaice per period	8058	9008	17807	24898	25405	42936
No. of hauls ,, ,,	69	71	83	73	67	58
Av. Plaice per haul ...	116	127	214	341	379	740
	1910-12	1911-13	1912-14	1913-15	1914-16	1915-17
Total Plaice per period	45215	48585	31163	23297	18201	6184
No. of hauls ,, ,,	73	87	100	83	68	38
Av. Plaice per haul ...	619	557	312	281	268	163
	1916-18	1917-19	1918	1919		
Total Plaice per period	4589	5430	2357	1990		
No. of hauls ,, ,,	33	29	11	12		
Av. Plaice per haul ...	139	187	214	166		

ON THE RESULTS OF A DRIFT BOTTLE EXPERIMENT MADE IN 1913.

By R. J. Daniel, B.Sc.

In July, 1913, a number of Drift Bottles were released from the Lancashire and Western Sea-Fisheries steamer, "James Fletcher."

The type of bottle has already been described, and although the notice enclosed was somewhat modified, there was no essential difference fron the original one used.*

Eighty bottles in all were set free, from eight different stations. Seven of the stations lay on a line east and west (true) from Holyhead to the Kish Light Vessel, Dublin. The first station was made 10 miles west (true) of the North Stack, and six subsequent stations were spaced at distances of five miles from each other.

The line was run on July 2nd during an ebb tide, and on the following day, July 3rd, on the return journey, the eighth station was established in Lat. 53° 18′ N., Long. 5° 24′ W., that is, $1\frac{1}{2}$ miles South (true) of Station IV, and approximately in the centre of the channel, between Holyhead and Dublin.

The following table gives the order in which the bottles were released :—

		Station.	No. of bottles released.	Card numbers.
July 2nd.	9.40 a.m.	I	10	1—10
	10.10 a.m.	II	10	11—20
	10.50 a.m.	III	10	21—30
	11.20 a.m.	IV	10	31—40
	11.50 a.m.	V	10	41—50
	12.15 p.m.	VI	10	51—60
	12.45 p.m.	VII	10	61—70
July 3rd.		VIII	10	71—80

*Professor W. A. Herdman, F.R.S. Report for 1894 on Lancashire Sea-Fishery Lab., page 37.

The number of bottles recovered was 20 or 25% of those released; of these three were recorded from the south coast of Ireland, outside the Irish Sea area altogether, and two others were stranded on the north east coast of Ireland, after making comparatively long journeys.

Five bottles were washed ashore during August, and these were recovered on the Welsh coast. Four of them were found within eight miles of each other on the Carnarvon Bay Coast of Anglesey, three on August 24th and one on August 25th. The fifth was found further south, off Borth in Cardigan Bay, on August 26th. These five bottles represent the Stations I, IV, VI, VII, that is they come from the East, Centre and West parts of the line upon which they were distributed. Examining the Meteorological Office Reports for the Weather Observation Stations at Holyhead and Dublin (Phoenix Park), one station on each side of the Channel, it is seen that during the period July 2nd to August 26th (inclusive), the following statements may be deduced from the wind records:—

Holyhead—

The wind blew from a westerly quarter 33 more days than it did from an easterly quarter.

The wind blew from a northerly quarter 23 more days than it did from a southerly quarter.

Dublin (*Phoenix Park*)*

The wind blew from a westerly quarter 24 more days than it did from an easterly quarter.

The wind blew from a northerly quarter 23 more days than it did from a southerly quarter.

Moreover, on the average northerly and westerly winds were a little stronger than winds from opposite quarters.

The directions of the prevailing winds were such that the general surface drift of water due to them would be south-east (true) in July and south-east by east (true) in August. Finally, these bottles were recovered during a period of onshore winds.

* There are two other Meteorological Stations in Dublin but, during the periods under survey, their records are very similar to Phoenix Park.

Only one bottle was washed ashore during September. This bottle (No. 70, Station VII) was found on the 4th off Harlech, after three days of off-shore winds. Its later appearance might possibly be due to local conditions in Tremadoc Bay, which forms a cul-de-sac where the flood and ebb runs practically at right-angles to the beach.

The remaining bottles, fourteen in number, were all recovered on the Irish coast during dates included in 5th-20th October. Nine of the bottles were beached on a twenty-six miles stretch of coast between Malahide, Co. Dublin, and Dunary Point, Co. Louth. These nine bottles represent Stations II, III, IV, V, VI and VIII; none belonged to Station VII, which was nearest the Irish coast. Again, as with the bottles stranded on the Welsh coast, stations from all parts of the line contributed.

Considering the period August 27th to October 5th we find that from the grounding of the last bottle in August, until the date of recovery of the first bottle in Ireland, the winds were as follows :—

Holyhead—

The wind blew from an easterly quarter 18 more days than it did from a westerly quarter.

The wind blew from a northerly quarter 16 more days than it did from a southerly quarter.

Dublin (Phoenix Park)—

The wind blew from an easterly quarter 9 more days than it did from a westerly quarter.

The wind blew from a northerly quarter 4 more days than it did from a southerly quarter.

If the period is extended to October 18th, the day on which the last of the nine bottles was found, there is practically no difference in the general direction of the wind. Surface drift due to wind, then, would be to the westward and southward. These bottles were recovered during a period in which, on the whole, there was a prevalence of off-shore winds. The

five remaining bottles travelled, as mentioned above, comparatively long distances.

Two apparently crossed the "still water" area between the Isle of Man and Dundrum Bay, Ireland, and were recovered one off Strangford and the other on the Antrim coast. The distance of the latter from its original station was 115 miles, and the drift gives an average of 1·2 miles per day. Although it seems strange that these bottles traversed an area in which the tide shows a rise and fall and practically no horizontal movement, it may be noted here, that in 1894-5 experiments in which 440 bottles were recovered out of the 1,045 liberated, nearly 12% crossed this area.

It may just happen that they were carried over during a short period of southerly winds, and assisted to some extent by the slow constant current which there is reason to believe flows northward from the George's Channel and out through the North Channel.

Of the three bottles picked up on the South Coast of Ireland one travelled 238 miles, a resultant average over the ground of 2·31 miles per day. It is known that the ebb-tide in the southern area of the Irish Sea strikes over towards the Irish coast, and it is possible that these bottles may have been carried by it down the Irish coast.

No bottles seem to have crossed the line between the Calf of Man and Holyhead, and to have entered Liverpool Bay.

The number of bottles released was small and the experiment was too isolated to enable one to draw any definite conclusions. It may be noticed, however, that of the twenty bottles recovered there are two marked groupings; one of four bottles on the Anglesey coast, found on two successive days in August, and a larger grouping of nine bottles on the east coast of Ireland, all recorded in October.

Both groups, although found on opposite coasts, contain bottles representing stations from all parts of the line upon

The following is a tabulated list of the results:—

No. of Bottle.	Date and Position Set Adrift.				Date and Position when Recovered.					Resultant Distance and Direction.	
		Station.	Lat.	Long.			Lat.	Long.		Miles (Naut.)	(Mag.)
6	2.7.13	I	53° 19⅓′ N.	4° 57½′ W.	24.8.13	Aberffraw Beach	53° 10½′ N.	4° 29′ W.	Anglesey.	19½	S. 40° E.
34	...	IV	53° 19⅓′ N.	5° 22½′ W.	25.8.13	Cymmeran ,,	53° 9½′ N.	4° 28½′ W.		34	S. 55° E.
57	...	VI	...	5° 39′ W.	24.8.13	Rhoscolyn Head	53° 13⅔′ N.	4° 37′ W.		38	S. 64° E.
61	...	VII	...	5° 47′ W.	24.8.13	Aberffraw Beach	53° 9½′ N.	4° 28′ W.		49	S. 59° E.
70	...	VII	...	...	4.9.13	Harlech	52° 51⅓′ N.	4° 8½′ W.	Cardigan Bay	77	Devious.
3	...	I	...	4° 57½′ W.	26.8.13	Borth	52° 29⅓′ N.	4° 4′ W.		82	,,
16	...	II	...	5° 6′ W.	18.10.13	Dunany Pt.	53° 51½′ N.	6° 13½′ W.	East Coast of Ireland.	53	N. 33° W.
77	3.7.13	VIII	53° 18′ N.	5° 24′ W.	11.10.13	...	...	...		46	N. 24° W.
28	2.7.13	III	53° 19⅓′ N.	5° 14′ W.	5.10.13	South of Dunany	53° 49⅓′ N.	6° 15′ W.		48	N. 32° W.
18	...	II	...	5° 6′ W.	8.10.13	Clogher Head ...	53° 47′ N.	6° 14′ W.		50	N. 37° W.
71	3.7.13	VIII	53° 18′ N.	5° 24′ W.	12.10.13	Termonfeckin ...	53° 45′ N.	6° 14½′ W.		42	N. 30° W.
35	2.7.13	IV	53° 19⅓′ N.	5° 22½′ W.	14.10.13	River Boyne	53° 42⅓′ N.	6° 14½′ W.		38	N. 35° W.
56	...	VI	...	5° 39′ W.	8.10.13	Ben Head	53° 37⅔′ N.	6° 13′ W.		32	N. 28° W.
20	...	II	...	5° 6′ W.	11.10.13	Rush	53° 31′ N.	6° 5′ W.		38	N. 54° W.
49	...	V	...	5° 31′ W.	12.10.13	Malahide	53° 27′ N.	6° 7′ W.		24	N. 53° W.
29	...	III	...	5° 14′ W.	6.10.13	Cushenden Bay	55° 7⅔′ N.	6° 1½′ W.	N.-E. Coast Ireland	116	Devious.
40	...	IV	...	5° 22½′ W.	14.10.13	Strangford	54° 24′ N.	5° 26½′ W.		65	N. 16° E.
59	...	VI	...	5° 39′ W.	14.10.13	Tucunshen	52° 11′ N.	6° 27′ W.	South Coast Ireland	80	—
50	...	V	...	5° 31′ W.	12.10.13	Calf Island, Schule, Co. Cork,		Howes Beach		238	—
33	...	IV	...	5° 22½′ W.	18.10.13	Head of Kinsale, Co. Cork.				188	—

which they were set free. On the same date, and at the same spot (Aberffraw Beach), Bottles No. 6 and No. 61 were found, one having been cast into the sea at Station I and the other at Station VII, thirty miles away.

The general direction and strength of the tidal streams in the Irish Sea are fairly well known. The ebb-tide is the reverse of the flood, except in the southern area as mentioned above. On the whole, therefore, the distance a floating object travels with the flood will be counterbalanced during the subsequent ebb. Apart from these tidal movements the wind is bound to affect bodies floating near the water surface by causing a drift in the upper layers of water, and also by creating wave motion.

Considering the prevailing winds during the period of release for the Welsh bottle, it is seen that they tend to cause a decided drift to the southward and eastward, which coincides with the general drift of these bottles. Add to this the fact that the bottles were washed ashore during on-shore winds, and one might be inclined to conclude that they had been strongly influenced by the wind.

Taking the period between the recovery of the bottles in Wales and the group of nine bottles in Ireland *i.e.*, August 26th to Oct. 5th-18th, the prevailing winds were such as to cause a general drift to the westward and southward.

The dates of the Welsh and Irish bottles are clearly marked with a difference of a month between them, and the change from prevailing westerly winds to easterly winds coincides with the landing of the Welsh bottles. One might be led to assume, therefore, since one bottle from the extreme Station VII was found in Wales, that all bottles had journeyed towards the Welsh coast, and that those which failed to land had drifted back towards Ireland. This would mean, however, that the drift on the return journey would be at the very least 4-6 miles per day, which seems excessive.

Moreover, during the whole of the time July 2nd to October 5th to 8th, between these dates westerly winds predominated over easterly winds by a minimum of six days. This may be seen from the following statements :—

July 2nd to August 26th. Minimum number of days of winds with predominance from a westerly quarter are given by Dublin records and consist of 24 days.

August 27th to October 5th. Maximum number of days of wind with predominance from an easterly quarter are given by Holyhead and consist of 18 days. The maximum difference between the Holyhead and Dublin records gives 24 days in favour of westerly winds.

In spite of this predominance of westerly winds a greater number of bottles were found on the Irish than on the Welsh coast.

Again, the whole period of release of the bottles was marked by persistent northerly winds ; yet of the seventeen bottles recovered in the Irish Sea, the eleven bottles from the Irish coast are further north of the line of stations, than the six bottles from the Welsh coast are to the south of it. This points to a general tendency of a drift of surface water to the North in spite of prevailing winds. It is the resultant of all such forces as tide and wind upon the surface layers of water which determines the movements of drift-bottles and which will affect in a like manner the abundance of fish embryos and food existing in the upper layers of the sea.

Such organisms existing between Holyhead and Dublin during July would have some chance of being off the Welsh coast in August, and a much greater one of being near the coast of Co. Dublin and Co. Louth in October.

That such movements may be influenced by fortuitous conditions is apparent from the behaviour of the three bottles Nos. 33, 34 and 35. Released at the same station, one was

picked up off the Head of Kinsale, another in Anglesey, and the third at the mouth of the River Boyne.

This segregation may be accounted for by the action of small local differences. Examples of these are eddies and convection in the water, such as may be observed as far out as twenty miles from Holyhead, due to the impinging of that part of the tide which is following the coastal formation, upon the central mass of water moving steadily up the centre of channel; water ripples which may be due to the presence of banks and shallows, or even a catspaw of wind. These are enough to disperse drift bottles in the earlier part of their histories, and may determine into which general system the bottle is finally going to be adopted.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART XII.

By W. A. Herdman, F.R.S., Andrew Scott, A.L.S., and H. Mabel Lewis, B.A.

We had hoped to close this series of statistics and issue a final report on this occasion, but pressure of other work has rendered it impossible during the present year to undertake the necessary full discussion of our accumulated data and a careful re-consideration of the results arrived at in these interim reports. We deal, therefore, again with the observations and results of the past year only.

The work during 1919 has been carried on in exactly the same manner as in previous years, and 536 samples of plankton were collected in the neighbourhood of Port Erin, and have since been worked up in detail. These bring the total number of samples for the 13 years' work, since 1907, up to 6,498.

In addition to an average of six gatherings per week throughout the year in Port Erin Bay, in the specially important months of March, April, July, August and September, special hauls were taken both in the bay and outside in the open sea from the motor-boat "Redwing." The results have been treated in the usual way, and the forms, lists, tables and graphs are stored available for future reference. The following is only a summary of the outstanding facts of the year.

The vernal plankton maximum was again in May, and the largest total catch with the standard net was 99 c.c., taken on May 9th, 1919. The monthly average catch rises from about* 3 c.c. in January and February, to 12 in March, 20 in April, to the climax 36 in May, and then falls to 21 in June, 7 in October, and so down to the minimum of 3 again in

* We give the nearest whole numbers.

December. The Diatoms taken by themselves form the usual double-crested curve with a greater maximum in May, a minimum in August and a second lower maximum in November. The monthly average for Diatoms in May was about 5 millions, and in November 400,000. The largest single catch of Diatoms was 16,669,000 on May 9th. These numbers for the vernal maximum in May are much lower than in the previous year when (May, 1918) the average for the month was 26½ millions, and the largest single catch was over 73 millions (May 21st).

It may be useful to state here that the distance traversed in each of our 15 minutes hauls is as nearly as possible half-a-mile, and we estimate our usual rate of towing to be about 2 miles per hour.

The Dinoflagellate maximum was in July when the monthly average was 130,404. It had risen from about 8,000 in January and fell to about 4,000 in September, with a second rise to 10,000 in November. The largest single haul of Dinoflagellates was 318,200, on July 28th, mainly composed of *Ceratium tripos*. The largest haul of *Peridinium* was 55,200 on July 21st.

The highest monthly average for the Copepoda (both in the adult condition and as Nauplii) was in June (100,354 adults, and 37,425 Nauplii) though the largest individual catch was in July (126,563 on July 31st). These times are unusually early for Copepoda. Last year the highest monthly average was in August, and the largest single catch in September. This year (1919) we had the unusual phenomenon of the Diatoms being still abundant (in the millions per haul) at the time of the Copepod maximum. Moreover, it is exceptional to have the maximum of the Dinoflagellates later than that of the Copepoda.

Taking our usual seven dominant genera of Diatoms more in detail, we find from the monthly averages that two of them,

Biddulphia and *Coscinodiscus*, have their spring maximum in March, other two, *Rhizosolenia* and *Guinardia*, in June and the remaining three, *Chaetoceras*, *Lauderia* and *Thalassiosira*, in May. An unusual though not unprecedented feature is to find that *Biddulphia* attains to higher numbers in November than at the spring maximum.

Another unusual feature this year is the relative scarcity of the large Copepod *Calanus finmarchicus* which in place of invading the bay in quantity in July as it has done in previous years was in 1919 very poorly represented. The only catch above 1,000 was 1,240 on June 5th. *Pseudocalanus elongatus* was on the other hand more abundant than last year and was present in quantity from May till November. The highest record was 36,340 on June 9th. *Oithona similis* was also unusually abundant, and at its maximum in June and July gave nine hauls of over 50,000, the highest being 115,280 on July 31st. The six important genera *Calanus*, *Pseudocalanus*, *Temora*, *Centropages*, *Acartia* and *Oithona* all show maxima in June, while *Paracalanus* has its maximum in September.

In view of the enormous quantities of *Noctiluca* that Mr. Scott obtained in the Barrow Channel in December it is interesting to notice that at Port Erin the numbers were comparatively low, the largest hauls (up to 26,200) were in July, and some months of the year in both spring and autumn showed none at all.

The other chief organisms of the plankton—*Oikopleura*, *Sagitta*, Cladocera, Medusæ, Ctenophora and the various groups of larvae—have not shown any special features in their occurrence during 1919, but corroborate more or less exactly the conclusions arrived at in previous years.

Phyto-plankton in Relation to Fish Larvæ.

We drew attention in last Report to the very small number of different kinds of organisms—both plants and animals—that make up the bulk of the plankton that is of real importance

to fish. One can select about half-a-dozen species of Copepoda which constitute the greater part of the summer zoo-plankton suitable as food for larval or adult fishes, and about the same number of generic types of Diatoms which similarly make up the bulk of the available spring phyto-plankton year after year. "It is this fact that gives great economic importance to the attempt to determine with as much precision as possible the times and conditions of occurrence of these dominant factors of the plankton in an average year" (Report No. XXVII, p. 32). An obvious further extension of this investigation is an enquiry into the degree of coincidence between the times of appearance in the sea of the plankton organisms and of the young fish, and the possible effect of any marked absence of correlation in time and quantity.

Most of the food-fishes in our seas produce floating (pelagic) eggs, which hatch out as larvae in spring at periods varying from February to May* according to the kind of fish and the temperature of the water—a low temperature in general retarding the spawning and subsequent development. The marked increase in the number of Diatoms (phyto-plankton), especially *Chaetoceras*, which causes the vernal plankton maximum, begins to show at the very period when the fish larvae are produced in greatest quantity, viz., March and April, in the Irish Sea. The Diatoms vary somewhat in their abundance and date of first appearance from year to year, and the question arises—are they also, like the fish larvae, retarded in development by the low temperature in a late season so that there comes to be some correspondence in date between the larvae and the natural food upon which they are dependent after the absorption of their food-yolk ?

Dr. Johan Hjort† has recently made the interesting

* A few exceptional occurrences extend the range from January to September.

† *Conseil Internat. Explor. de la Mer. Rapports et Procès-Verbaux.* XX, p. 205, 1914.

suggestion that, if on occasions the larvae are hatched out before their food, the phyto-plankton, is present in sufficient abundance, there may then be an enormous mortality of larvae which will affect the young fish population of that year and greatly reduce the numbers of that particular year-class of that fish in the commercial fisheries of successive years for some time to come (depending upon the average age of that species of fish). So that, in fact, the numbers of a year-class may depend not so much upon a favourable spawning season as upon a coincidence between the hatching of the larvae and the presence of abundance of phyto-plankton available as food.*

In a general way, the curve for the spring maximum of pelagic fish eggs in the Irish Sea begins to rise late in February and remains high throughout March and April, and occasionally later. The Diatom curve also starts towards the end of February and remains high throughout March, April, May and June. There is evidently a general correspondence between the two maxima, but is it sufficiently exact and constant to meet the needs of the case? The phyto-plankton may still be relatively small in amount during February and part of March in some years, and it is not easy to determine exactly when, in the open sea, the fish eggs have hatched out in quantity and the larvae have absorbed their food-yolk and started feeding on Diatoms.

If, however, we take the case of one important fish—the plaice—we can get some data from our hatching experiments at the Port Erin Biological Station which have now been carried on for a period of seventeen years. Although the present Biological Station was erected in 1902, the first stock of adult plaice could not be received into the spawning pond until the winter of 1903-04 and the number of fertilised eggs skimmed from the pond and of larvae set free from the hatchery

* For the purpose of this argument we may include in "phyto-plankton" the various groups of Flagellata and other minute organisms which may be present with the Diatoms.

were only about one million in that first year of work. From 1904 onwards the numbers have been much larger, and we have records for each year of the quantities dealt with and of the dates when the first fertilised eggs were seen, when the various batches of eggs were placed in the hatching boxes and when the larvae were taken out to sea.

Systematic intensive study of the plankton in Port Erin Bay was commenced in 1907, but previous to that, although frequent plankton gatherings were taken for the use of those working at the Biological Station, no statistics were kept. Consequently, complete series of figures for a comparison of the dates for fish larvae and phyto-plankton can only be given for the fourteen years from 1907 to 1920 inclusive—and these show a certain amount of correspondence and also a certain amount of divergence.

It may be objected that our data in regard to the fish eggs and larvae may possibly have been affected by artificial conditions, and so do not necessarily agree with the state of affairs in the sea outside. That point has been carefully considered and probably need not be regarded. The fish pond at Port Erin receives water from the sea daily, and although the temperature* of the water differs on occasions from that of the bay the differences do not seem to be so great or so constant as to affect the results. Temperatures in both pond and sea have been taken twice daily (at 9 a.m. and 4 p.m.) for a number of years, and although in summer the pond is warmer than the open sea, and in winter colder, there seems to be no further constant relation, the temperature of the pond being—especially in spring when the spawning is in progress—sometimes a little higher and sometimes a little lower and sometimes the same as that of the sea. There is on occasions, however, in spring a distinct difference in the alkalinity, the pond water

* A. Dannevig has shown that there is a close relation between the temperature of the sea and the quantity of eggs produced by the fish in a hatchery or pond—the intensity of the spawning increasing with every rise of temperature (see *Canadian Fish Eggs and Larvae*, Ottawa, 1918).

being the more alkaline—that is, having less carbon dioxide—which is due, according to Professor Benjamin Moore, to the greater amount of photosynthesis in progress, caused by the relatively greater quantity of green algæ growing on the walls of the pond.* Whether this reduced amount of carbon dioxide would have any effect either in increasing or retarding the spawning and subsequent development of the fish has not yet been determined.

In looking now at the records of the hatchery for the seventeen successive years (1904 to 1920, inclusive) we find that the dates for the first observed fertilised eggs range from the middle of January, 1920, to March 3rd, 1904). Excluding these two records as exceptional, we have a run of 15 consecutive years with dates ranging from February 5th to 26th, and the average date for the first fertilised plaice eggs in the Port Erin pond is about February 20th. The average temperature of the pond at that time is 40° F.

The dates of the first hatching of larvae in these years ranges from February 9th, 1920, to March 30th, 1904, and the average date is about March 13th, when the average temperature of the water is 41° F. The dates when the first larvae are set free in the sea have varied from February 23rd (1914 and 1920) to April 10th (1904), and the usual date is about March 20th, when the sea-water temperature averages 44° F.

Turning now to our records of the phyto-plankton in the sea, we find that the earliest date in the 13 years (1907-1919) is February 5th (1907) and the latest April 13th (1908). Omitting February and April, we have a run of ten consecutive years (1910 to 1919) when the dates range from March 4th to 22nd, and a central date for the beginning of the Diatom increase in spring may be taken as about the middle of March. The actual phyto-plankton maximum ranges in these years

* Moore finds that a shore pool at Port Erin full of growing green weed is distinctly more alkaline than the water of the bay, in April.

from April 5th (1907) to June 15th (1915), and an average or central date would be about the middle of May.

It is evident then that in most of these years the Diatoms were present in abundance in the sea a few days at least before the fish larvae from the hatchery were set free. Looking at the records for the individual years, we find that out of the 13 years (1907-1919) in nine cases (1907, 1910-12 and 1915-19) the phyto-plankton preceded the appearance of the larvae, and that it was only in the remaining four years (1908, '09, '13 and '14) that there was apparently some risk of the larvae finding no phyto-plankton food, or very little.

The evidence so far seems to show that if the fish larvae are set free in the sea as late as March 20th, they are fairly sure of finding suitable food ;* but if they are hatched as early as February they run some chance of being starved.

It would be interesting to know whether the fishes of the four years noted above, when the first larvae preceded the phyto-plankton increase by from 10 to 16 days, have been poorly represented in the fisheries of subsequent years. It may be, however, that any variations in the abundance of the year-classes due to the quantity of food available for the larvae is counterbalanced by that periodicity in the productivity of the plaice fisheries which has been demonstrated by Dr. Johnstone, and which is dealt with in the case of the Mersey Estuary by Mr. Daniel in the present report.

Our records for the present year (1920) are not yet fully made up, but so far as observations show it appears to be the earliest year of our series. The plaice in the pond must have commenced spawning in January as we found hatched larvae as early as February 9th, and we put a first batch of larvae out to sea on February 23rd. The plankton contained some Diatoms (*Biddulphia* and *Coscinodiscus*) as early as January,

* All our dates and statements as to occurrence refer to the Irish Sea round the south end of the Isle of Man.

but up to the end of March, by which time a considerable number of larvæ had been liberated at sea, there was still no great abundance of phyto-plankton. It is possible, therefore, that the year-class 1920 may be poorly represented in future fisheries, if the plaice larvae hatched out naturally in the sea were on the average as early as in our pond and assuming that they were dependent upon the Diatoms* for food.

NOTE.—In concluding this Report, I desire to express the hope that during the coming year I may be able to undertake a re-consideration of the accumulated data of these 14 years (1907-20 incl.) of plankton work in the Irish sea, and to offer in some future report a general summary of those results that seem to be sufficiently established.—W. A. HERDMAN.

* It is possible that in addition to smaller organisms such as Flagellates they may also make use of various minute invertebrate embryos and larvae such as those of some Echinoderms, worms and Molluscs, and of *Oikopleura* which is usually fairly abundant in the plankton at the time.

C. TINLING AND CO., LTD., PRINTERS, 53 VICTORIA STREET, LIVERPOOL